IEEE Journal on Selected Areas in Communications
September 1994, vol.12, no. 7

Switching Equipment Adaptation for Russian Public Telephone Network

Boris S. Goldstein

***Abstract* – This paper describes the adaptation and certification process for switching equipment to be used in the Russian public switched telephone network (PSTN). The first part of the paper illustrates the basic certification procedure and its essential steps. Each step, whether it is described in a natural language or formally in a specification language SDL, is an integral part of the certification process. The described approach improves standardization in the way that specialists at different manufacturers as well as Russian telecommunications engineers use the same methods, the same specification language, and the same test environments. Even the documents for different switching equipment have standardized features. In the second part of this paper, the specification methodology based on formal methods has been shown to work in the adaptation and certification process. It does reduce the number of software errors in the resulting version of adopted switching equipment, and it does improve quality and productivity significantly.**

I. INTRODUCTION

SINCE the start of the Russian digital switching equipment age with the introduction of DX-200 Telenokia (Finland) digital exchange in 1982, the development of interexchange signaling system interfaces and specific call handling procedures has been the major focus in adapting modern telecommunications equipment to the former USSR Public Switched Telephone Network (PSTN). During the past ten years, much progress has been made to convert this process into an engineering design that better serves real needs.

Special software development is the most critical part of digital switching systems adaptation, so it is necessary to support the design process by an effective methodology. Such a methodology has been applied in the adaptation activity of Leningrad Telecommunication R&D Institute (LONIIS). This L-methodology is based on the ITU-T recommended specifications and description language (SDL) and does not require special programming tools or special computing environments, but must be supported by a minimum set of procedures for process organization.

II. NEED FOR DIGITAL SWITCHING SYSTEM ADAPTATION

Great changes that are currently taking place in the former USSR concerning politics, geography, law principles, and the economic system cannot help but reflect on electrical communications as a whole and on public switched telephone networks (PSTN) specifically.[1]

In the state of transferring to a market economic system, the Ministry of Telecommunications monopoly is being wrecked, alternative communication structures are arising, and the sources and character of telephone network financing are being changed.

[1] Manuscript received April 13, 1993; revised March 9, 1994. The author is with the Leningrad Research Institute of Telecommunications, Warshavskaya, Leningrad, Russia. IEEE Log Number 9402755.

There are some negative aspects of telecommunications decentralization that may lead to great material losses for the country's economics. To overcome such negative tendencies and to support a well-based unified technical policy in the field of local telephone networks is the goal served by the Leningrad R&D Telecommunication Institute (LONIIS) in its development of a methodology of adaptation and certification of modern digital switching systems. The main goal of the methodology is to support a development process aimed at ensuring compatibility of the signaling systems and specific call handling procedures in the existing analog telephone network with modern switching equipment.

It is understandable that the replacement of analog exchanges with digital exchanges in a short time is not possible in one of the largest telephone networks in the world. The analog local and toll exchanges and toll and international operator switching centers will remain a big part of the network for many years. All existing urban exchanges interwork by using a variety of signaling systems on three-wire and two-wire analog trunks as well as pulse-code modulation (PCM) on digital trunks. With the exception of a few foreign-made digital exchanges, the existing switching systems can provide neither common-channel signaling (ITU-T No. 7), nor other ITU-T signaling systems (Rl, R2, etc.) used in the world. Specific Calling Party Number Identification (CNI) procedure, introduced in the late-1960's, required that every local exchange send multifrequency packets with the calling subscriber number and category as an answer to a CNI-request (B-answer line signal and 500 Hz tone as explained in [9]).

Another specific requirements is to handle, with preemptive priority, semiautomatic (operator-controlled) calls. Implementing all existing systems and call handling procedures into digital exchanges is extremely expensive. A significant element of the cost is the additional software in the digital exchanges needed for interworking with the existing analog network. Therefore, an analysis and development of an adaptation process is a very important component of the Russian switching network digitalization.

During the last decade, the Leningrad R&D Telecommunication Institute (LONIIS) has been conducting a large project encompassing the adaptation and the certification of foreign and domestic switching systems for the Russian Public Switched Telephone Network (PSTN). In this paper, the author attempts to share his experiences in that project.

The certification methodology means a set of methods and means of interface specification, norms, rules, and procedures for digital exchanges installed into the Russian PSTN. The methodology includes also a set of programs, techniques, simulations, and measuring devices for testing and verification of the above specification.

The usefulness of this methodology can be verified by the adaptation results of the various digital switching systems for central offices and PABX. Among those systems are

1) central offices: 5ESS (AT&T), EWSD (Siemens), TDX (designed by the Korean companies DAEWOO, Goldstar, OTELCO, Samsung), Linea UT (Italtel), NEAX-61 (NEC), DMS-100 (Northern Telecom), System 12 (Alcatel), System X (GPT), AXE-10 (Ericsson):
2) PABX: Hicom (Siemens), OMNI (ATEA), Starex (GoldStar), Meridian (KAPSCH), A4300 (Alcatel), NEAX-2400/7400 (NEC), UE (Tesla), Coral (Tadiran).

The paper is organized as follows. Section II describes the general adaptation and certification procedure conducted by LONIIS on behalf of the Russian Ministry of Telecommunications. The contents of the first official document "Technical Terms and Conditions" are described in this section. Section III contains the development methodology with more detailed specifications and the multilevel hierarchical structure of these specifications. Section IV reports the specifications examples from different levels obtained for one frequency in-band 2600 Hz signaling system. The summary and conclusions are presented in Section V.

III. CERTIFICATION PROCEDURE

The basic principle for the certification work is the need for a unified technical policy for development of telephone communications, networks, common standards, and well-based development plans of PSTN.

The switching equipment certification procedure in the Russian Ministry of Telecommunications is illustrated by the simplified flow chart in Fig. 1. Here the title pages of the official documents are represented as explanatory notes on the left side of the figure. The procedure itself is based on requirements of the former USSR "PSTN set of Rules and Standards" [1], as well as on the analyses of the actual practices and operations of the local telephone networks, including the signaling systems, CNI equipment, charging principles, and maintenance. Where possible, the ETSI and ISO standards and ITU-T recommendations are also taken into account. Based on the technical description of the switching equipment to be certified, and on the materials mentioned above, the general specifications are stated and unified in the document entitled "Technical Terms and Conditions" (TT&C). Fig. 2 outlines the contents of the TT&C. Every item in this document should be verified by experts representing LONIIS and experts representing the manufacturer of this switching equipment. Then the TT&C should be agreed upon by a responsible representative of the manufacturer, by the LONIIS director, and by the Ministry of Telecommunications.

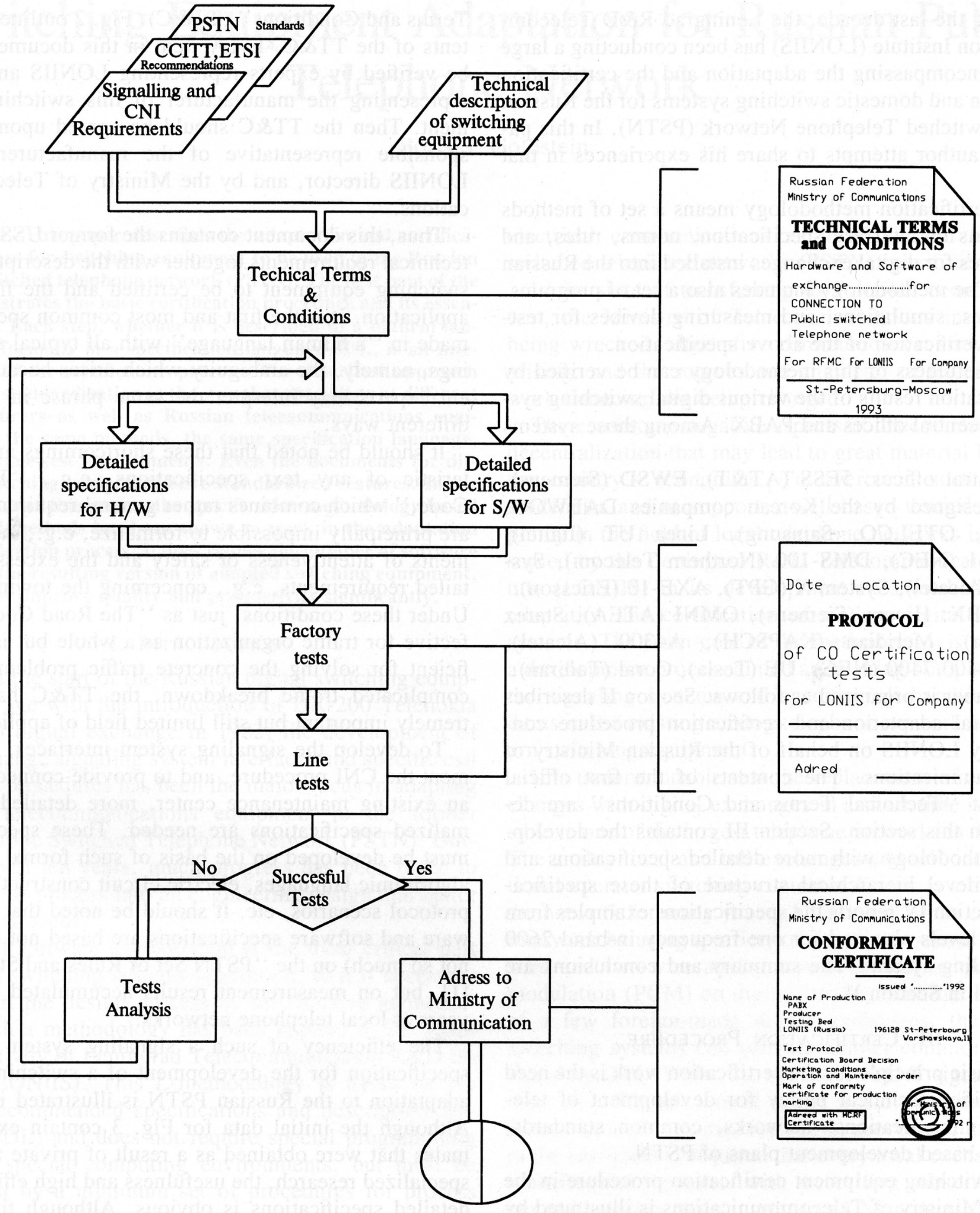

Fig. 1. Switching equipment certification procedure.

Thus, this document contains the former USSR general technical requirements together with the description of the switching equipment to be certified and the field of its application. It is the first and most common specification made in "a human language" with all typical shortcomings, namely, the ambiguity which arises because different experts may interpret the same phrase in TT&C in different ways.

It should be noted that these shortcomings are characteristic of any text specifications, e.g., "The Road Code," which combines rather general requirements that are principally impossible to formalize, e.g., the requirements of attentiveness or safety and the excessively detailed requirements, e.g., concerning the towing length. Under these conditions, just as "The Road Code" is effective for traffic organization as a whole but is not sufficient for solving the concrete traffic problem, so in a complicated traffic breakdown, the TT&C has an extremely important but still limited field of application.

To develop the signaling system interfaces, to implement the CNI procedure, and to provide connection with an existing maintenance center, more detailed and formalized specifications are needed. These specifications must be developed on the basis of such formal means as algorithmic languages, electric circuit construction rules, protocol scenarios, etc. It should be noted that the hardware and software specifications are based not only (and not so much) on the "PSTN Set of Rules and Standards" [1], but on measurement results accumulated for many years at local telephone networks.

The efficiency of such a signaling system interface specification for the development of a switching system adaptation to the Russian PSTN is illustrated in Fig. 3. Although the initial data for Fig. 3 contain expert estimates that were obtained as a result of private and fairly specialized research, the usefulness and high efficiency of detailed specifications is obvious. Although the investments needed at the first stage is greater, later on they will be compensated by the manpower spared during the design and debugging.

The important parts of the specifications are signaling and CNI test methodologies and scenarios. Generally speaking, certification "Tests Program and Methodologies" should correspond to the whole contents of "Technical Terms and Conditions" (see Fig. 2) and should cover all technical requirements that are mentioned in this document. Almost 70% of certification tests can be done at the factory, where the equipment is produced. During the factory tests, it is sometimes possible to use the existing test protocols, for example, for climatic or mechanical TT&C requirements tests. Usually, during the factory test, maximum attention should be paid to such characteristics as an overvoltage protection, transmission characteristics, etc.

The smaller but most important part of certification tests is done during the field tests in the actual Russian PSTN. It can also be done in the LONIIS Certification Center. At the Center, the mixtures of real trunks from existing step-by-step and crossbar exchanges together with unique protocol-testers, signaling systems simulators, and CNI analyzers are provided. According to the author's personal point of view, it is very useful to pass the Line Test in LONIIS Certification Center not only for certification purposes but also for debugging new options of the adapted switching equipment.

After a successful completion of certification test (see Fig. 1), all test protocols should be sent to the Russian Ministry of Telecommunications to receive the final Certificate. The title page of this Certificate is also shown in the lower right corner in Fig. 1.

IV. SPESIFICATION TECHNIQUES FOR ADAPTATION DESIGN

Fig. 4 shows the same adaptation and certification process as in Fig. 1, but the process is described from the engineering point of view and in greater detail. This spiral model of switching equipment adaptation is built by an analogy with the well-known Boehm's model of the software process [3, Fig. 2]. The analogy is quite understandable also because the software remains the most critical part of an adaptation design as it has been during the adapted switching equipment initial development. Some incompleteness of the spiral model follows from the well-known law of continuous alterations of Biledy and Le-man: "The operating system is subject to continuous alterations until the moment comes where it would be more profitable to freeze it and make it anew."

TECHNICAL TERMS AND CONDITIONS
for connection with Public Switched Telephone Network
CONTENTS

1. INTRODUCTION
1.1. Subject of Technical Terms and Conditions
1.2. Field of application
1.3 General Description of System
2. SPECIFICATIONS
2.1. Exchange Capacity, Telephone Traffic, Efficiency
2.2. Types of Communications, Basic Modes of communication
2.3. Types of Subscriber's Lines and Subscriber's Sets, Categories of Subscribers and Services
2.4. Subscriber's Lines Parameters
2.5. Subscriber's Line Signalling
2.6. Types of Trunks, Trunk Parameters
2.7. Trunk Signalling
2.8. Release principles
2.9. Transmissions Characteristics
2.10. Communication with exist Urban Telephone Network
2.11. Acoustic and Ringging Signals
2.12. Calling Subscriber Number Identification
2.13. Charging
2.14. Synhronization
2.15. Operation and Maintenance
2.16. Service Quality and Reliability Demands
2.17. Resistance to Climatic and Mechanical effects
2.18. Resistance to External Electric and Electromagnetic Fields
2.19. Spare Parts Tools Measuring Instruments Devices and Consumable Materials
2.20. ISDN Services. Data transmission facilities
2.21. Control Devices
2.22. System Software
2.23. Power Supply
2.24. Technical Documentation
3. SYSTEM DIMENSIONS (contents of delivery)
4. ACCEPTANCE TERM AND TESTS
5. SUPERVISION METHODS. DOCUMENTS USED DURING INSTALLATION, TESTS AND MAINTENANCE
6. MAINTENANCE AND OPERATION INSTRUCTIONS
7. PACKING, MARKING AND TRANSPORTATION
8. PRODUCER GUARANTEES
9. MODIFICATION OF TECHNICAL TERMS AND CONDITIONS.

Fig. 2. Contents of the document "Technical Terms and Conditions."

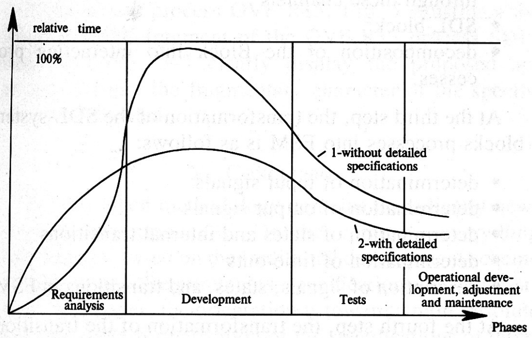

Fig. 3. Time for adaptation of switching equipment to former USSR Public Switched Telephone Network without (1) and with (2) detailed specification of signaling systems, CNI procedures, etc.

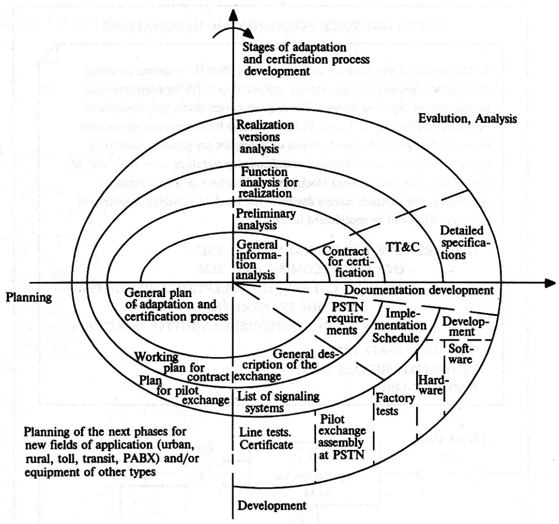

Fig. 4. Spiral model of the adaptation process.

IV. Specification Techniques for Adaptation Design

This concept defines the specifications characteristics at every level of the model in Fig. 4 by an analogy with ANSI/IEEE Standards [5] in the following way: definite-ness, i.e., unambiguity of interpretations; completeness; verification ability; clearness, i.e., tracing ability; and usefulness at the development and operation stages. Besides, for any type of connection with the existing Russian PSTN, the multilevel specification (according to the model in Fig. 4) is considered complete if it includes the essential requirements concerning the given signaling system, determines the types of incoming and outgoing line signals under different situations, all scenarios of signals exchange, all diagrams and time-out tables with detail inscriptions and definitions.

The specification hierarchical levels, along the spiral in Fig. 4, differ not only in the degree of concretization (which is being increased from the top downwards) but also in the linguistic means of description. Thus, the presentation of specifications at a higher level is in a sense like a "common ancestor" of the lower presentation families. With the exception of the very first level – Technical Terms and Conditions–that uses a human language, at the next more detailed levels, the graphical syntax is commonly applicable with Pascal-type notations which were united by the experts of ITU-T Study Group 10 into a single Specification and Description Language (SDL) [6].

The use of the SDL language presents several advantages: it is an ITU-T standard; the graphical form SDL/GR clearly shows the structure of a signaling system of its signals exchange; and the finite state machine model is well suited for the signaling logic and call handling procedures specifications. In this methodology, the SDL language [7] is used for the description specification, design, documentation, debugging, and test purposes.

The SDL is based upon the conception of interaction between processes. The sets of processes form the block. In its turn, the *system* is formed by blocks, connected with each other and with their environment through *channels.* The behavior of each process is determined by an extended finite state machine (FSM) that performs the operations in answers to external digital actions (signals). The FSM has a terminal memory of internal states and operates with a finite discrete assemblage of inputs and outputs. For each combination of input signal and state, the next stage is set (possibly coinciding with the current one). Unlike the classic FSM, the SDL allows the possibility of nonzero duration transition from state to state. Additionally, the SDL determines the mechanism of a simple queue for signals, coming at the instant when the process is in transition from one state to another.

In conformity with the methodology described in Fig. 4, the following parameters are determined at the second step of the specification (after the TT&C):

- SDL-system
- decomposition of the system into SDL-blocks
- determination of channels and the signals transmitted through these channels
- SDL-block
- decomposition of the Block into interacting processes.

At the third step, the transformation of the SDL-isystem blocks processes into FSM is as follows:

- determination of input signals
- determination of output signals
- determination of states and internal transition
- determination of time-outs
- description of signals, states, and transitions in FSM

At the fourth step, the transformation of the transitions obtained by FSM into SDL transitions is carried out, so that each transition is initiated by an external even, i.e., SDL-diagrams are drawn up. The SDL-diagram graph reduction is also performed at this step.

Such a hierarchy of presentations (SDL-system, blocks, processes, channels, signals) is displayed with the help of the examples illustrated in Fig. 5-7. Fig. 5 shows the example of the SDL-system for one-voice-frequency (OVF) signaling system on 2600 Hz for Russian rural PSTN. Usually this type of signaling is used between the rural central office or between suburban-rural tandem node and toll exchange. Trunks between these exchanges are named ordered-connection links (ZSL) for outgoing calls and toll connection links (SLM) for long distance incoming calls. Note that the OVF signaling system is much different from the ITU-T Rl signaling system.

Fig. 6 describes one of the blocks of the one-voice-frequency SDL system. The block specifies OVF signaling logic for incoming toll calls through SLM. The block consists of one process OVF R13. Fig. 7 illustrates the IDLE STATE fragment of the OVF R13 process SDL-diagrams. Fig. 5-7 clearly display the proposed approach, despite the fragmentary character of the specifications illustrated.

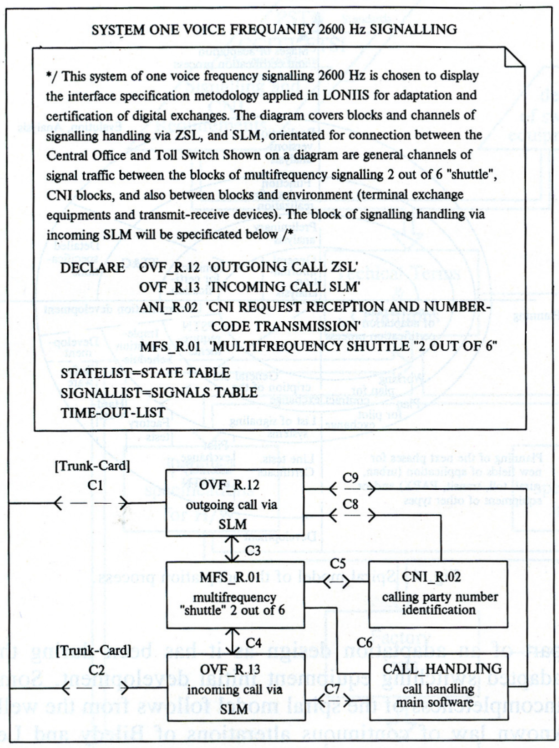

Fig. 5. Diagram of block information on SDL for single-frequency signaling system.

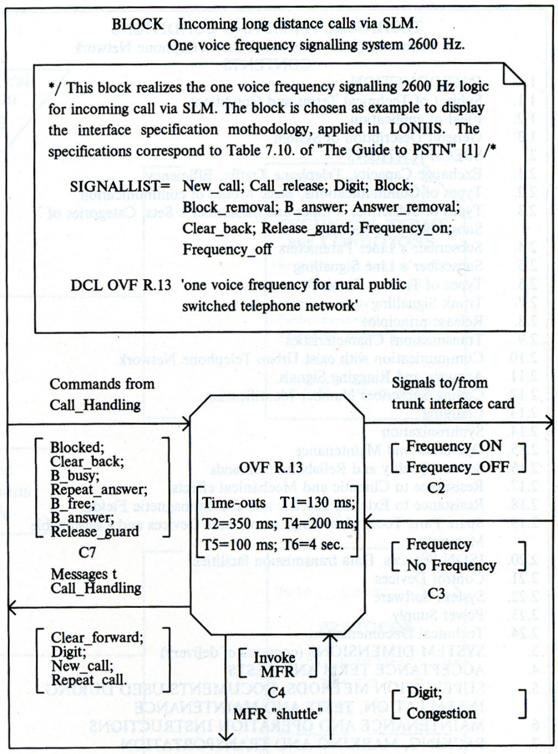

Fig. 6. Structure of one voice frequency 2600 Hz signaling handling block on SDL for incoming connection via SLM.

V. CONCLUSION

The described methodology contains no radically new, revolutionary principles. On the contrary, everything mentioned is based on the traditional development scheme of the type "requirements-specifications-design-testing." Moreover, the orientation is toward a more resolute and consistent formalization of the specifications of interfaces with the existing PSTN. Principle attention is paid to the total combination of switching equipment testing methods–aiming for them to be in full conformity with these formalized interface specifications.

Such a shift emphasis in a rather traditional combination of telecommunication equipment adaptation and certification procedures generates in a sense, a new quality and thus allows us to hope that the author's attempt to formulate and state in writing the practical experience accumulated in LONIIS may appear helpful–if not as a guiding principle, at least as one of the possible points of view.

REFERENCES

[1] USSR Public Switched Telephone Network, Set of Rules and Standards, Moscow, Preyskurantisdat, 1988 (in Russian).

[2] J. Ludewig and H. Matheis, "Specification techniques for real-time systems," *Computer Standards & Interfaces*, vol. 6, pp. 115-133, 1987.

[3] B. W. Boehm, "A spiral model of software development and enhancement," *Computer*, vol. 21, no. 5, 1988.

[4] B. S. Goldstein, A. E. Koucheryavy, and L. G. Sloutsky, "International Cooperation: Foreign exchange adaptation to the USSR telephone network," in *Proc. Conf. ICCC-92*, vol. 2, Geneva, Italy, 1992, pp. 641-646.

[5] *IEEE Guide to Software Requirements Specifications*, ANSIIEEE Std 830-1984 USA.

[6] ITU-T: Recommendations Z. 100 to Z. 104, Specification and Description Language (SDL), Blue Book, Geneva, 1989.

[7] B. S. Goldstein, "The software development technology for digital switching systems," *Electrosvjaz*, vol. 10, 1988.

[8] R. Moretti, "SDL and object oriented design: A way for producing quality software," CSELT Technical Rep., vol. XVIII, no. 2, Apr. 1990.

[9] B. Goldstein, and L. Slutsky, "Public telephone network in the former USSR," this issue, pp. 1161-1170. ,

Boris S. Goldstein, photograph and biography not available at time of publication.