Multipurpose Radio for Railways. Construction and Applications

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Abstract—This paper provides information on the construction and presents experience from the “Koliber” project: a modern multipurpose radio system for railways. The radio equipment is produced by Radionika Ltd., and was designed in cooperation with Department of Electronics, AGH University of Science and Technology. Discussed here are system architecture, technical and functional parameters, and innovative radio system applications possible thanks to its innovative construction.

Index Terms—VHF railway radio, GSM-R

I. INTRODUCTION

"Koliber" is a modern solution for radio communication, designed exclusively for railway needs. The device works as a mobile set in double-cabin locomotives of all types and in any other rail vehicles. The stationary version of the radio is intended to work as a base station, operated by the railway dispatcher.

The device provides radio connections of all types in radio networks operated by railway companies, using VHF 150MHz band. The device provides a specific signaling used in Polish railways: tone selected calls (Zew1, Zew3) and emergency train stop protocol [1], [2]. Among the mandatory functions presented above, the solution offers more advanced functions available in contemporary radio communication. In particular, the device enables a range of functions including selective call signaling (SelCall), CTCSS/DCS encoding and decoding, modem data transmission, and GPS navigation.

Furthermore, the architecture and technology of the equipment allow also using the device in other communication network standards (including GSM and GSM-R). Besides the obvious economic benefits (single device supporting multiple communication systems), this solution significantly simplifies the operation of radio for railway vehicle drivers and dispatchers. "Koliber" is a solution that not only serves the needs of current users of the railway network but also ensures the operation of equipment after modernization of the network and during switching to a new digital communication standard.

The entire set is powered through a universal DC/DC converter, working within a wide range of voltage (15... 212V). Single-cabin locomotive sets have only one DMI mounted, while stationary sets feature an AC/DC power supply mounted instead of the DC/DC converter. Moreover, the open architecture of the device enables integration of any ready-to-use GSM-R external modules [3]. To date, successful integration with certified PortBox Ultralight GSM-R module of HFWK (formerly Kapsch) was performed.

III. DRIVER-MACHINE INTERFACE MODULE

The DMI (Driver-Machine Interface) module performs the role of the user’s interface radio. Its main operational elements include:

- high resolution graphic LCD display with backlight,
- contextually illuminated numeric and functional keypad,
- “RadioStop” button being a part of the emergency train stop system,
- set of signaling LEDs,
- microphone with the PTT (Push To Talk) key,
- speaker,
- 1-Wire interface for identification/authentication.

The block diagram of the DMI module is presented in Fig. 2. It is a typical microcontroller application based on a 8-bit Atmel RISC ATmega128 device. The DMI features a...
large and clear graphic LCD display unit with resolution of 240×64 pixels to present the current state of the whole radio set. The display presents also contextual description of the keyboard functions. The meaning of particular keys depends on the menu selected, and contextual illumination facilitates their operation further. 1-Wire contact devices are used for access authorization and radio operator log-in & log-out. Communication with other modules of the set is performed via RS422 bus, while the radio voice is sent as analogue.

IV. SWITCH MODULE

The primary task of the switch module is commutation of signals between the radio module and the active DMI in one of the two locomotive cabins. This module was designed and developed as a natural replacement for the mechanical switch used before in most locomotives in Poland [4]. The switch module can optionally be equipped with the GSM Motorola G24 engine. This solution enables concurrent usage of the audio and data GSM services parallel to standard work in the VHF band. This allows using emergency calls as well as SMS.

What is more, once a GPS module has been installed, it is also possible to transfer train location data via the GPRS data link. The GPRS network link is a convenient medium for transmission of all kinds of status messages between the driver and the stationary rail service. The switch module architecture is presented in Fig. 3. It uses an ATmega128 microcontroller as the main processor. Due to the large number of serial port controlled modules, a quadruple UART is used. This module can also be used in stand alone mode, e.g. as an intelligent GPRS modem for localization systems and for various data acquisition solutions. To enable its operation even after the locomotive’s on-board supply failure (or while locomotive is being moved), the module is equipped with a power management system with a high capacity battery cell.

V. RADIO MODULE

The radio module contains the main execution unit for the whole set. The Tait TM8100 VHF transceiver module is used as the RF engine, and all the other functions – including audio signaling, data transmission and voice recording – are carried out by a dedicated unit control module.

Below listed are the parameters of the radio module:

- 134-174 MHz frequency VHF band,
- 256 radio channels,
- scanning,
- programmable channels frequency, RF power, and channel spacing,
- generation and detection of the emergency “Radiostop” signal,
- generation and detection of sub-audio CTCSS/DCS signals and selective call audio signaling,
- 1200/2400bps modem data transmission,
- call party ID generation and detection,
- radio voice and system event recording with optional external recording channel,
- GPS internal module option, external DCF module port,
- RTC clock.

The Fig. 4 presents the block diagram of the radio module architecture. The TM8100 VHF transceiver is controlled by a serial port with the Tait company proprietary command protocol. All RF parameters are controlled by respective appropriate software commands. A dedicated audio processor
CMX7041 chip from CML is used for all audio and sub-audio signaling, and also for modem transmission. In Poland, the call party ID signals are transmitted as modem messages.

The radio module is controlled by the same type of microcontroller (ATmega128 from Atmel). However, due to a significant need of hardware resources, the remaining module architecture is implemented in 200k gates FPGA Spartan3 device from Xilinx. The main subsystem implemented in FPGA is the Secure Digital flash memory card host controller. SD cards are used as the archive repository for voice and event records. To enable quick archive content reading without removing the SD card, an SD controller was designed to work in a high-speed parallel (4-bit data bus) mode with throughput exceeding 10MB/s. In addition, the FPGA implements an interface to a USB 2.0 controller, two UARTs (one for communication with the TM8100 VHF transceiver and the other for the service), two CVSD codec drivers (one for recording audio from the radio set; i.e. VHF GSM calls, the other for an optional external voice recorder), external data memory interface for the microcontroller, and the authentication subsystem based on a hardware implementation of Blowfish cryptographic algorithm with external “1-Wire” ID device.

The module uses a small backup battery for the real-time clock device. Time synchronization is provided by the GPS engine, which – in the case of desktop solutions – may be replaced with an external DCF77 receiver.

VI. SYSTEM FIRMWARE

Microcontrollers software was written in C language in the IAR AVR environment, and the FPGA project was created with VHDL.

The intelligent switch module with GPRS option uses UIP TCP/IP freeware stack [5]. The web server and client ensure HTTP support for the “post” and “get” commands. When the external monitoring device is connected, one can use the proprietary protocol to query the module for numerous parameters of the locomotive and localization. There is also an option to remotely change any EEPROM configuration memory content, e.g. the APN name and other GPRS network connection parameters.
The AVR bootloader feature may be used to change any module microcontroller program memory and/or the FPGA configuration memory content, which facilitates firmware upgrades.

All radio parameters can be set up using a dedicated software connected to the DMI module service RS232 port.

VII. APPLICATIONS AND EXPERIENCES

Based on the referred solution, some interesting applications of the radio set have been implemented. Their number includes:

- train localization and locomotive parameters monitoring system,
- DSR dispatcher system – remotely controlled VHF base station sets for railway main tracks,
- G.sHDSL modem for the radio remote control,
- GIS RSSI measurement system for railway tracks.

Presented below is a selection of screens and diagrams of the applications mentioned.

Fig. 9 presents “Oguar Qpilot” fleet management system architecture from Quantum Software S.A. The “Koliber” radio set sends localization data from GPS via the GPRS link to the company’s APN GSM infrastructure. Fig. 6 presents a sample GUI window from the application.

Fig. 7 presents real time visualization of the locomotive parameters from the “Koliber” switch module, connected to the CL400 module of the locomotive monitoring unit (manufactured by ZEPWN).

Fig. 9 presents an architecture of the DSR dispatcher radio system, which consists of several radio base stations controlled by dispatchers from the Local Control Center. Each base station includes up to 4 radios, along with a service DMI module and a control unit. Base stations are connected with Local Control Center by SDH based E1 links, forming a star structure.

Fig. 10 presents example results of the radio signal strength measurement system done with the “Koliber” set on one of the main Polish rail tracks.

VIII. CONCLUSION

A few years of using the “Koliber” system in railway radio networks allow the conclusion that the design based on a simple 8-bit microcontroller, equipped with few external devices for dedicated functions, is fully justified. The design was verified by approved industrial bodies, positively tested in the real consumer world, and opened many new application fields.

REFERENCES


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