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Application of the Modular Integrator for Soldier's C4I System Management on the Battlefield

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Abstract. The C4I (Command, Control, Communications, Computers and Intelligence) system is the integral part of soldier's Individual Combat System. This subsystem establishes new standards by providing soldiers with supporting information and therefore improving their knowledge. For that reason, the C4I system integrates all radio, electronic and optoelectronic & IT components, which are a part of the soldiers equipment. The C4I system ensures exchange of data, imagery, and audio between its users and elements of its environment. For the above functionality to be implemented, the C4I subsystem needs a device which will integrate the above-mentioned functionality in its configuration. The Modular Integrator is this kind of device. This paper describes the design and the functionality of the Modular Integrator used for soldier's C4I system management. The paper focuses on the design of the device and on the set of functions it can perform in the C4I system.

This work has been compiled from the paper presented during the 11th International Armament Conference on Scientific Aspects of Armament and Safety Technology, Ryn, Poland, September 19-22, 2016.

An innovative concept, involving integration of three separate devices in a single enclosure, i.e. a personal radio, a portable digital assistant and a mobile phone with a power supply system allows the Modular Integrator to be referred to as a device with "functional multiformity". A key aspect of the project implementation was also the adaptation of the device to psychological & physical attributes of its future users. This adaptation was accomplished through evaluation of the Modular Integrator in terms of ergonomics, technical aesthetics, anthropometrics and customization, user interaction, pressure force, thermal comfort and lateralization. This "3-in-1" researched and tested solution, developed to the 9th technology readiness level, has no match on national and on international markets.
Keywords: functional polymorphism, Modular Integrator, C4I system

1. OVERVIEW

The main goal of the "Modular Integrator for soldier's C4I system management" project was to develop and to manufacture the Modular Integrator (M-ITG) on the 9th technology readiness level. The design of the device turned out to be an interdisciplinary problem, requiring knowledge and experience in telecommunications, signal processing, mechanical design, antenna technology, software engineering, materials science, and ergonomics. Due to significant scientific & research burden, the task was completed by an interdisciplinary Polish Scientific and Industrial Consortium, which was formed by: WB ELECTRONICS S.A. – as the Consortium Leader, Military Aviation Medicine Institute – as the Consortium member, and PCO S.A. – as the Consortium member. The project was co-financed by Polish National Research & Development Centre under the Contract no. DOBR/0039/R/ID1/2012/03.

2. M-ITG's FUNCTIONAL POLYMORPHISM

The Modular Integrator is a device which integrates a personal soldier's radio station, a Personal Digital Assistant (PDA) computer, a mobile phone (smartphone) and battery power supply in a single enclosure. In result of this integration, the M-ITG acquires the functionality of a mobile phone combined with a computer and soldier's personal radio station. The term "functional multiformity" used above can be also referred to as "functional polymorphism" – as it applies to a single, autonomous device, in which functions dedicated to several completely independent devices have been integrated [1]. The following block diagram shows the structure of the Modular Integrator with the display.

Fig. 1. A photograph of the Modular Integrator for soldier's C4I system management, including a display

The Modular Integrator ensures access to optoelectronic and radioelectronic components of the soldier's C4I system through a single interactive display. M-ITG also performs audio-visual, navigational, and sensory functions by depicting in a legible way current tactical situation and by controlling data transmission and image processing tasks. The device also implements a mobile phone functionality, using the global GSM infrastructure. The personal radio station module, built in the device, automatically sets up and reconfigures MESH[1] networks, ensures concurrent voice and data transmission, transmits the current GPS position and video from a selected station. The Modular Integrator support of available tablets and smartphones (visualization and configuration over USB or Ethernet) and built-in AES 256 (Advanced Encryption Standard) encryption algorithms as well as optimization in terms of operational frequency selection and modulation patterns all make the M-ITG a fully network-centric solution [2, 3, 4].

Putting all these components into a single enclosure reduces the number of activities the soldier would have to perform, should they need to use each component of the device independently. This, in consequence, reduces the time of limited battlefield awareness and contributes to improvement in soldier's safety. Table 1 shows the technical specifications of the device.

[1] MESH – is a wireless communications network made up of radio nodes organized in a specially mesh topology in which each node relays data for the network. It is also a form of wireless ad hoc network.

Table 1. Technical specifications of the Modular Integrator for soldier's C4I system management.

TECHNICAL SPECIFICATIONS OF THE MODULAR INTEGRATOR	
CPU	i.MX515 (ARM Cortex-A8 800 MHz)
RAM	512 MB
Built-in storage	4 GB
External storage	2 ÷ 8 GB (SD)
Wireless interface	GSM, Wi-Fi 802.11 b/g/n & BT2.1 2.4 GHz ISM (Nordic Semiconductor's Proprietary)
Wired interfaces	6xRS-232, 5xRS-485, 3xUSB, 1xUSB OTG, 1xCAN, 2xEthernet 10/100BASE-T, 1xHeadset, 1xmicroSD, 1xSIM, 2xVGA, 4xComposite Video IN, 2xComposite Video OUT
GPS	Built-in GPS receiver with an antenna
Radio Module Frequency (RMF)	RMF UHF band: 350 ÷ 400 MHz RMF L band: 1.35 ÷ 1.4 GHz exchangeable RMF
RF output power of the Radio Module	1 W average / 8 W peak
Sensitivity	- 102 dBm @ 1 Mb/s (BER < 10e-6)
Modulation type - Waveform	HDR COFDM Waveform SDR module
Bandwidth	1.2 MHz
Range:	Up to 4 km (depending on the terrain)
Internal battery power	11.1 V / 2.6 Ah (Li-Ion) rechargeable battery Battery life up to 1.5 h
External power supply	12 -36 VDC Battery life (11.1 V/ 9.6 Ah dedicated Li-Ion battery) up to 5 h
Operating temperature:	From -30°C to +50°C
Water-tightness	Up to 2 m
Weight:	< 2.1 kg

3. M-ITG INTERNAL DESIGN

The Modular Integrator consists of the following functional blocks: A Personal Digital Assistant (PDA) computer module, a Personal Radio module, a Power Supply System module, and an additional module implementing GSM phone functionality.

The PDA module consists of the following components: A Central Processing Unit (supporting intelligent power management, with computing power sufficient to compress/decompress voice and video data streams in real-time and to ensure operation of opto/radio-electronic components of the C4I system), a Communication module (which supports C4I system's sensory devices and wireless communication with external hardware), Video Signal Management module (which is intended to convert analogue video signals from transducers to digital formats compatible with the Central Processing Unit and vice versa), Audio Signal Management module (responsible for converting analogue audio signals from transducers to digital format), the Power Management module (which handles intelligent control of electronic and sensory devices of the soldier's C4I system), Storage Memory (saving the information acquired and processed by M-ITG with the option of its further retrieval or transfer), the Positioning System (which allows soldier's location data to be fed to the electronic terrain map and to be broadcast in the radio network), a Wi-Fi network card (supporting wireless radio communication), a Mobile telephony modem (which supports radio access to the global GSM infrastructure).

The display of the Modular Integrator is an additional, separate element. It is connected with a cable and ergonomically placed on the soldier's load carrying equipment. The display features automatic power saving mode and ensures good visibility under strong sunlight and can display text messages, image messages and static imagery, and video streams.

3.1. Personal Radio Station module

Development of the Personal Radio Station module involved development of a compact module, featuring a digital signal processing technology, supporting waveform modification, which is an inherent feature of Software-Defined Radio (SDR) solutions [5, 6]. The Personal Radio module has the average output power of 1 W and a receiver with a noise figure not exceeding 4 dB. The selectivity of the analogue circuitry is up to 80 dB. The receiver dynamic range is between -97 dBm and -5 dBm. Transmit-to-receive switching takes about 10 μs and the module can be switched off to standby mode and its individual parts can be woken up within the same time.

The following functional blocks have been implemented for purposes of the Personal Radio module: the FFT/IFFT module, frame detector module (utilizing correlation methods), the interpolating module, the decimating module, the clock recovery module, the cyclic prefix insertion/reversal module, the time slot management module, the automatic gain control module, and interface modules.

Figures 2 and 3 show interconnections of the functional blocks related to data processing in the transmitting and in the receiving circuitry.

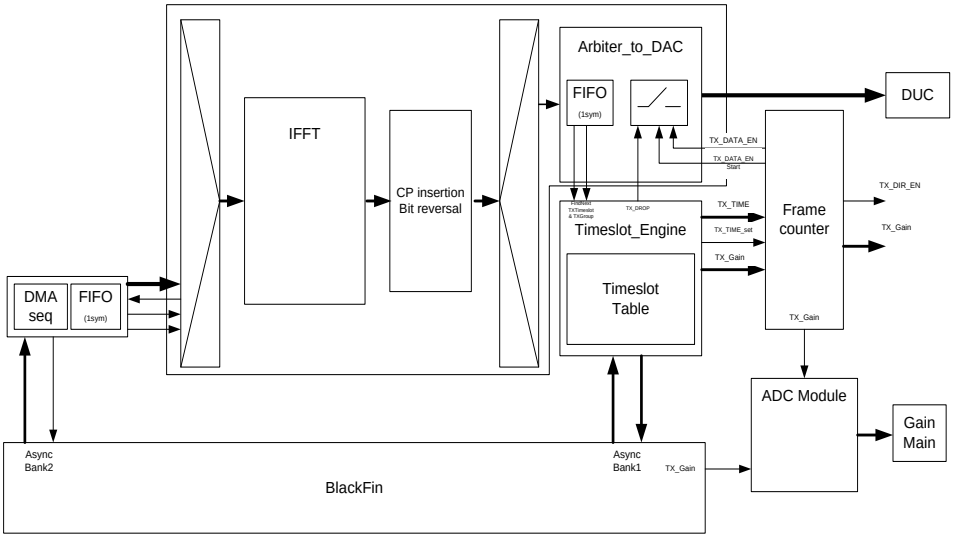

Fig. 2. Data processing in the transmit circuit

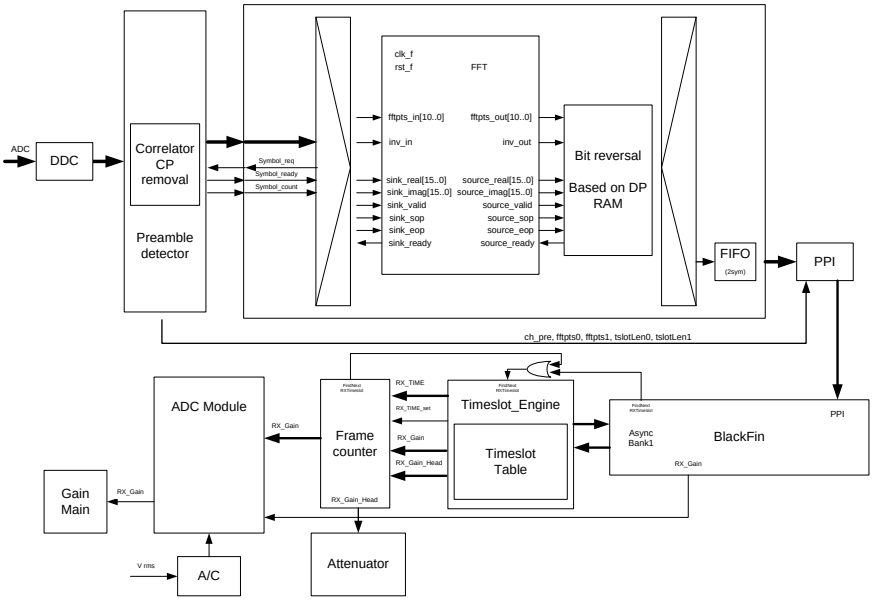

Fig. 3. Processing in the receiving circuit

Digital data, pre-processed in the DSP system in the frequency domain is forwarded for further processing by the DMA module as shown in Figure 2. Then, the data stream undergoes IFFT processing and is converted to the time-based form.

In the next step, the cyclic prefix is inserted to the signal (CP Insertion and Bit reversal module). The "Timeslot Engine" includes Timeslot Table and the "Frame Counter" modules ensure safe timeslot management mechanism. In the last phase, before the data stream is sent to further analogue processing stages, the signal is interpolated. Preprocessed analogue data stream undergoes decimation and is sent to the frame detector. After the FFT, a signal in frequency domain is obtained, and the data stream is sent for further DSP processing. The "ADC Module", the "Frame Counter", and the "Timeslot Engine" perform the functions of automatic gain control required for correct reception of radio signals from radio stations located at various distances from the receiver as shown in Figure 3.

4. CONCLUSIONS AND FUTURE DEVELOPMENT

Soldiers need to carry out their combat tasks in highly urbanized areas, in urban areas as well as in rural, wooded areas, indoors, in tunnels or inside buildings. Due to the varying properties of these areas, the propagating electromagnetic field and therefore tactical and technical parameters of the radio communication equipment may be significantly limited by a number of negative effects, associated with such propagation patterns [2, 4, 7]. Having the above considerations in mind, an innovative device has been designed, which constitutes the main part of the soldier's C4I system. Parasitic propagation effects have been reduced by optimal selection of operating frequency bands and modulation schemes of the radio station module, which was integrated in the single M-ITG enclosure. The device's ability to set-up MANET[2]-type networks, to perform navigation and sensory tasks, to handle communication, audio-visual and control functions and its significant resistance to natural interference and enemy jamming attempts as well as effective and fast data transmission with the option to use the GSM network. All these make the Modular Integrator the first device of this kind, completely new on the international technical & industrial market.

By integrating in a single device, three completely different existing components (a radio station, a smartphone, and a PDA) a specific convergence has been achieved, creating a fully functional product while at the same time minimizing the weight for the entire C4I system, ensuring its simple an intuitive operation.

An additional and a very important task was the ergonomics and optimization research conducted on a group of special forces' soldiers using the Modular Integrator.

[2] MANET – Mobile Ad hoc NETwork – is a continuously self-configuring and infrastructure-less network of mobile devices connected wirelessly.

It shall be mentioned that the conducted research is particularly valuable from the solution optimization perspective, in terms of general ergonomics and that it constitutes an important part of the project [8, 9]. The WB Electronics S.A.'s goal is to develop an ultimate M-ITG application for operational assignments carried out by special operations forces, to utilize the M-ITG in the TYTAN Future Soldier program, to use the M-ITG in the EvaCopNet project and to ensure convergence of the solution with other projects currently under development, such as MICROS – the micro-sensory technology of vital functions measurements.

The Modular Integrator for soldier's C4I system management has been recognized with prestigious DEFENDER 2015 award on the International Defense Industry Exhibition in Kielce (Poland), in the "soldier's individual equipment hardware" category. In July 2016, the „Promilitaria XXI" Foundation awarded an honorable mention for the M-ITG as the best solution in the area of innovation and safety, and during the XI International Armament Conference the M-ITG presentation has been recognized with the 1st place and the Award of BUOS Sp. z o. o. President, for creative application of scientific research results in practice.

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Modułowy Integrator do zarządzania systemem C4I żołnierza

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Streszczenie. Integralnym elementem Indywidualnego Systemu Walki żołnierza jest podsystem C4I. Podsystem ten, wprowadza nową jakość jaką jest wsparcie żołnierza w informacje, a tym samym w wiedzę. Z tego powodu C4I integruje wszystkie elementy radiowe, elektroniczne oraz optoelektroniczne i informatyczne będące na wyposażeniu żołnierza oraz zapewnia wymianę danych, obrazów i fonii pomiędzy użytkownikiem i elementami jego otoczenia. Aby powyższe funkcje mogły być realizowane, podsystem C4I musi zawierać w swojej konfiguracji urządzenie, które zintegruje opisane wyżej funkcjonalności. Takim urządzaniem jest Modułowy Integrator. Niniejszy artykuł opisuje projekt budowy oraz funkcjonalność Modułowego Integratora do zarządzania systemem C4I żołnierza. W artykule zwrócono szczególną uwagę na budowę tego urządzenia oraz zbiór funkcji jakie urządzenie to realizuje w podsystemie C4I. Innowacyjny pomysł polegający na integracji w pojedynczej obudowie trzech różnych urządzeń, tj.: radiostacji osobistej, przenośnego komputera osobistego oraz systemu zasilania, realizowany na IX poziomie gotowości technologii, pozwolił określić Modułowy Integrator mianem urządzenia o „funkcjonalnej wielopostaciowości". Kluczowym aspektem realizacji projektu było również dostosowanie urządzenia do cech psychofizycznych przyszłych użytkowników. Powyższe dostosowanie zostało zrealizowane poprzez ocenę Modułowego Integratora w aspektach ergonomii, estetyki technicznej, antropometrii i personalizacji, interakcji z użytkownikiem, siły nacisku, komfortu termicznego oraz lateralizacji. Opracowane, przebadane oraz przetestowane rozwiązanie „3 in 1" nie ma swojego odpowiednika na rynku krajowym jak i na rynkach zagranicznych

Słowa kluczowe: polimorfizm funkcjonalny, Modułowy Integrator, system C4.