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# System for Internal Communication and its Implementation in Military Tactical Communications Network

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**This paper presents the System for internal communication and its functional compatibility with embedded subsystems inside the command armored vehicle. The paper discusses about possible effects of different types of electromagnetic interference on use of the device and the potential solution. Analysis of the obtained results and functional checks of the device aim the presentation of modernity, perspective and ability to meet the rising demands in future different and heterogeneous network technology. The diversity and complexity in managing this device have been the main driving factors in the evolution and enhancement of the military communication to provide control for not only packet based domains, but also to reduce voice and data latency transmission and to increase the response for battle request in real time. In this paper the method and technology which suggest possible application in the military environment where this device can resolve the problems of several network and devices types are shown.**

*Key words*: **armored vehicle, CUJ, EMC, helmet-phone, PJ, radio devices, UK-8, VHF and HF frequency range, VoIP technology, WEB server.**

## Introduction

INFORMATION communication technology maintenance is one of the most important military activities which are supposed to create the conditions for real time battle activities. Basic needs of military communication and information support are: voice and data transmission, protection of voice and data (including COMSEC and TRANSEC key) and electronic data processing. Network communication failure means failure of the whole military command system [1]. Quality of information generated and distribution time directly affect the implementation of the decisions making process [2]. Concerning these matters, we have witnessed a wide deployment to enhance the IP (Internet Protocol) suite to support traffic engineering. Future development of the network communication is conditioned by application of new communication technologies for network information exchange.

Special attention has been given in realizing parallel voice and data transmission and correct voice detection in the transmission channel since all parts of military communications are based on quick response for tactical requests in a short period of time. One of the useful ways to achieve those requirements is a choice of operating system. Using of Linux operating system on the Central Control Unit has created the possibility of working with an existing open source Asterisk VoIP server. However, on the VoIP client side (Control Unit), the NXP's Kinetis K64F microcontroller was realized. The advantages of this solution are exceptional performance, scalability and low power consumption using the built-in real time MQX operating system. This operating system supported everything needed for such a client, modular architecture, multitasking mode, including TCP/IP stack with the necessary peripheral drivers. But, the disadvantage of this solution is that it did not support any of the existing open source servers. This is why our own VoIP server/client with the accompanying SIP protocol has been realized.

Full control of RTP and SIP messages later enabled the software implementation of RS232 transmission over Ethernet (SOI - Serial over IP) and voice detection on the existing hardware. In parallel, voice, RS232 data and voice detection are transmitted in the channel with control of these tasks and their priorities in the same application without making additional connections (socket, message queue), which would only increase the delay in the already critical software implementation. Implementing these functions into the System for internal communication, the integration with radio stations VHF and HF frequency range was enabled.

One of the main problems in modern communication is how to ensure the proper operation of electronic, electrical and electromechanical devices in their electromagnetic environment without creating inadmissible electromagnetic interference to any other device in the environment. In the EMC chapter the procedure of laboratory testing is given and it describes the way in which the problem of the influence of electromagnetic interferences on the device's operation has been resolved.

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Also, this paper presents electrical and mechanical conditions of the devices' use without degradation of functional and electric characteristics. In this purpose, the device has been tested in laboratory and in realistic operating conditions according to the military standards. Exploitation tests have been carried out in different weather times and also by integration into multiple different platforms of combat and noncombat vehicles. Functional verification was performed in stationary conditions and in movement. The procedure of the laboratory testing was repeated in several different institutions in the purpose to get the most precise and relevant results. Using different measuring equipment with a setting of similar or identical measuring environment, the results were compared and their impact on the subject asset was performed.

In the Technical specification chapter the basic information about the System for internal communication (Central Control Unit and Connection Unit) are presented. In the next chapter the operating terms of use and functional characteristics which are provided with the device are shown. In the third and fourth chapter the measurement results of the climatic and mechanical conditions of use and the electromagnetic characteristic are given.

## Technical specification of the device

System for internal communication is implemented in an Integrated connection system such as:
- Tactical communication center,
- Command, armored and special purpose vehicle (tanks, mobile artillery guns, infantry combat transporters, emergency and fire vehicles),
- Ships and other boats.

Also, the System for internal communication can be used in an industrial factory and traffic infrastructure.

Voice communication into combat and command armored vehicles is realized using headphones with microphone. Depending on the type and purpose of the vehicle and the crew member role, audio interfaces could be realized such as:
- Helmet-phone with laryngophone,
- Micro-telephone combination with Push to Talk taster,
- Headset combination with Push to Talk taster,
- Speaker with ear-set (with Push to Talk taster),
- Speaker or loudspeaker.

In addition to the voice communication between crew member into a vehicle, the device could provide the voice communication between crew member into a vehicle with distance radio members in command places. The voice communication is realized in VHF and HF frequency range. The voice communication could be realized in conference or selective call (point to point).

Also, in addition to the voice communication, the device could provide data transmit towards the Local area network. The functionalities such as data transmit and voice communication are realized by applying the Power over Ethernet technology.

All announcements of incoming calls and current connections are accompanied by sound and light signals. Also, there are warnings about the occurrence and existence of alarm conditions in form of audible indications.

Mechanical constructions and dimensions of the device unit are adopted to the efficient use of space into telecommunication centers, combat and command armored vehicles.

There are following elements in the basic set of the device:
- Central control unit (*CUJ*),
- Connection unit (*PJ*), 6 pieces,
- Helmet-phone (*ŠM-1*) with finger button (*UK-8*), 6 pieces,
- Signal and power cables.

*Central control unit (CUJ)*

Central control unit provides useful signal and power for all connection unit PJ which are integrated in a command armored vehicle applying PoE interface which meet the *IEEE 802.3* standard. In this way the packaged data can be transmitted at speed up to 100Mbit/s. Power for PJ is realized over signal pairs in voltage range (44 – 57) V and maximum current consumption up to 350mA.

CUJ provides the ability to remote elements of the composition set using LAN and WAN interfaces which meet the *IEEE 802.3* standard.

Central control unit is powered by a DC power supply in voltage range (20.4 – 48) V. The system consumption in steady state, at the room temperature is:
- CUJ independetly up to 25W,
- CUJ with 6 PJ up to 85W.


**Figure 1.** Central control unit (front and back panel)

On the Central control unit, in Fig.1, the audio interfaces 2xVHF and 1xVF towards radio devices are implemented. Also, on the front side of the Central control unit there is a ON/OFF switch, then a switch to reset the configured parameters to fabric defaults, and a LED panel with the appropriate light signaling.

The electric resistance of the insulation has been tested in a certified laboratory according to the SORS 5574/03 standard. The test is realized by connecting direct current test voltage of 500V for 1 minute between the input contacts of the direct current power supply and the ground of the central control unit. The results of the measured values are shown in the Table 1.

**Table 1.** Electric resistance of the insulation CUJ

| | Electric resistance of the insulation toward ground (case) | Permissible (limit) value |
|---|---|---|
| DC input A | $5.77 \times 10^9\ \Omega$ | $\geq 0.1 \times 10^9\ \Omega$ |
| DC input B | $7.3 \times 10^9\ \Omega$ | |

Central control unit has implemented protection against wrong polarity of one-way source. Grounding of the both poles of the battery is also permitted (positive and negative pole of the battery). The electric characteristics of the switching current, sensitivity and permissible disturbances to the direct current supply line are realized according to the *ETSI EN300 132-2* standard.

Based on the given method standard the switching current of the Central control unit was measured when supplied from a DC voltage source and at maximum load. A representation of the test configuration on the basis of which the measurement of the switching current was realized is shown in Fig.2.

The evaluation criterion is defined based on the characteristics of the maximum switching current for telecommunications equipment at the standard power voltage supply and maximum load which is shown on the next diagram, in Fig.3. The results of the measured values are shown in Fig.4.

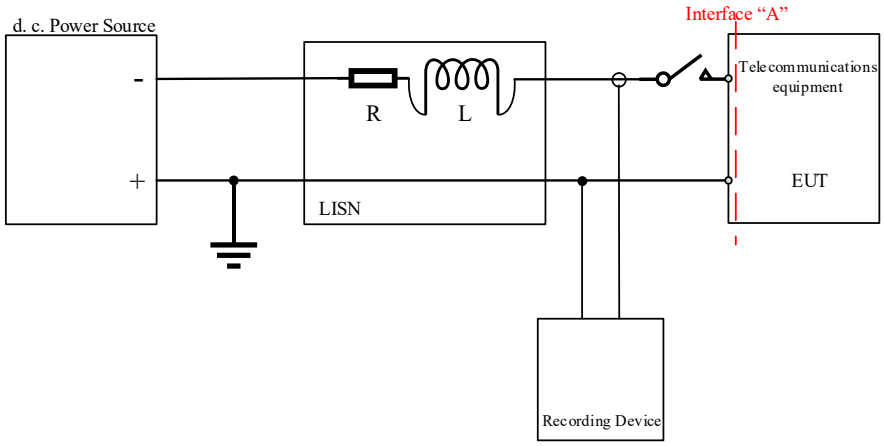


**Figure 2.** Testing configuration for measuring the switching current according to method ETSI EN300 132-2 standard

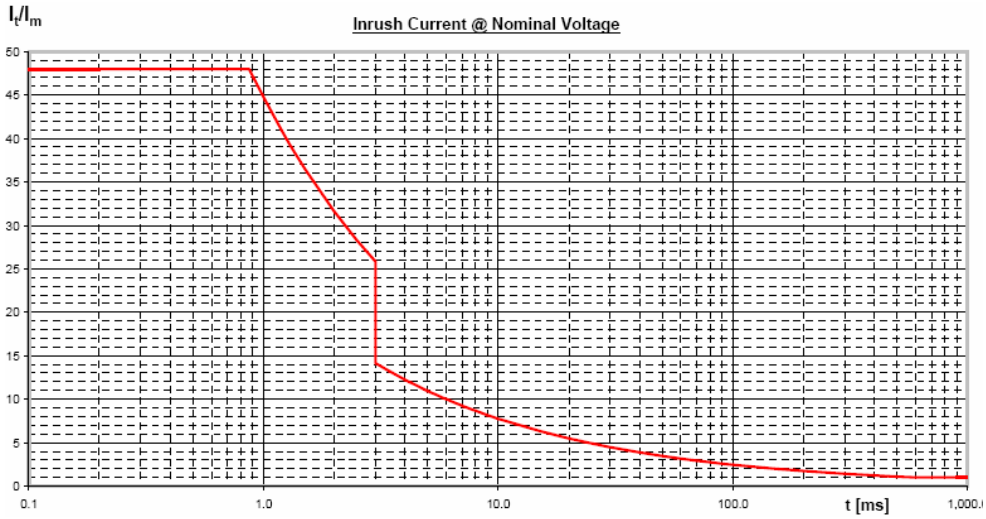


**Figure 3.** Characteristics of the maximum switching current for telecommunications equipment at standard power voltage supply and maximum load

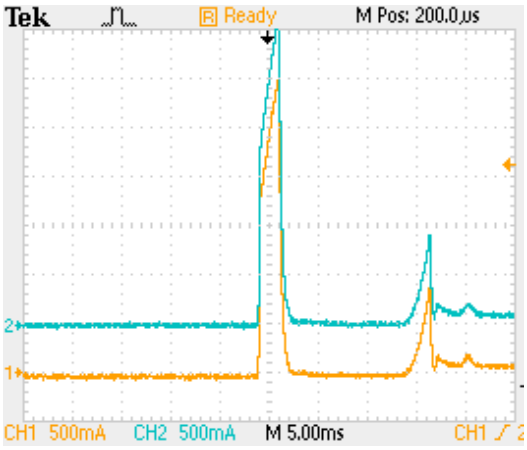


**Figure 4.** The maximum switching current of the Central control unit when supplied from a DC voltage source

According to Figure 4, it can be concluded that the peak value of the switching current of the Central control unit is about 3A and that the pulse duration is 3ms. Ratio of peak and maximum measured values is like:

$$\frac{I_t}{I_m} = \frac{3\ A}{0.82\ A} = 3.66 \qquad (1)$$

According to characteristic in Figure 3, it can be concluded that the obtained result is less than 40ms which is in accordance with the requirements of the *ETSI EN300 132-2* standard.

*Connection unit (PJ)*

Connection units are using all crew members into the vehicle. PJ has implemented a helmet-phone connection which is used to provide an audio signal toward the users. In addition, PJ provides a connection to CUJ applying PoE interface which meet the *IEEE 802.3* standard (technical characteristics of the PoE interface are descripted in the previous chapter). The power supply characteristics are defined by the technical characteristics of the PoE interface of the connection unit. Consumption of the connection unit at the room temperature is up to 10W.


**Figure 5.** Connection unit (front panel, upper and down side of PJ)

In the front side of the PJ (Fig.5) there is a numeric keypad which is used to manage services. Also, there is a LED panel to display the status of the device and the participation of individual connection unit in the available services. When the System is integrated in the vehicle, it is possible to connect each unit to ground individually.

In addition of the CUJ, the electric resistance of the insulation has been tested on the cable sections for all connection units. The measurement procedure is the same such as for the Central control unit. The results of the measured values are shown in the Table 2.

**Table 2.** Electric insulation resistance of cable sections

| | B | C | D | E | F | Permissible (limit) value |
|---|---|---|---|---|---|---|
| A | 123.3 GΩ | 96.4 GΩ | 165.5 GΩ | 183.5 GΩ | 201 GΩ | ≥ 0.1 GΩ |
| B | | 86.1 GΩ | 165 GΩ | 182.8 GΩ | 220 GΩ | |
| C | | | 32.2 GΩ | 114.8 GΩ | 175.9 GΩ | |
| D | | | | 142.3 GΩ | 223 GΩ | |
| E | | | | | 202 GΩ | |

Analyses of the obtained results conclude that the elements of the System for internal communication meet the requirements in terms of electrical characteristics.

## Characteristics of the system and operating terms of use

System for an internal communication provides a voice communication for all crew members into a command armored vehicle. Technology of the internal voice communication is based on VoIP protocol. The use of a helmet-phone with laryngophone enabled clear and understandable voice communication. This type of equipment is suitable for use in noisy environments such as the case in combat armored vehicles and transporters. The main role of the helmet-phone with finger switch UK-8 is noise reduction and to increase the useful signal.

Internal voice communication could be realized in conference or a selective call. It is possible to set the initial parameters on one of the tree predefined configuration for every participant individual. In this point of view, the systematization is achieved, as well as faster and easier use of the device in combat conditions. In every moment, it is possible to activate emergency call to all crew members in the vehicle for an important announcement. This type of the emergency is accompanied by sound and light signalization and this service is of the highest priority.

In according to the internal communication, it is also possible to establish external links by connecting the crew members with the distance radio members in VHF and HF frequency range. By applying the voice detection technique in the speech channel or by detecting service activation from radio network, incoming call or service notification detection to the radio operater in combat vehicle was performed. If needed, it is possible to initiate an outgoing call of radio participants by each crew member in the vehicle. Also, in certain tactical conditions, it is possible to perform radio silence and then the signal transmission from radio network is not allowed. If the combat vehicle participates in the formation of the radio intermediate station in order to broadcast the frequency parameters from one frequency range to other frequency range or just to extend the broadcast route, it is possible to monitor the whole communication between the stations by using the System for internal communication. In this way the compatibility of the device with the radio subsystem in the command armored vehicle is archived.

Internal communication between the crew members was realized in a stationary position and in movement, in conditions of the increased noise. The testing was carried out in self-propelled howitzer 122mm – *Gvozdika* and in the command armored transporters *KOT 1B13* and *1B14.* One example of an integrated system in those vehicles is shown in Figure 6. The main role of those vehicles is to provide transport, accommodation and work of the computing department of the division's battery during preparation and execution of artillery fire in all terrestrial and weather conditions. Using the System for internal communication it is possible to perform command, reconnaissance and fire control of the artillery units for fire support of the division's battery. In this way it has been shown that there is no degradation of the device functional characteristics in any conditions of combat use.

It is possible to maintain services of the System for internal communication by directly using PJ. In this way, every crew member could independently change signal level in earphones, tone level of the incoming call, entering/exiting a conference call, to initiate selective or emergency call, entering in radio network. Changing one of the tree predefined configurations it is allowed only to crew members with the highest priority level. In this way, traffic and also active connections control in the System for internal communication is possible. In turning on phase, the System for internal communication has implemented a procedure which is used to verify the correctness of the system and its subassemblies.

Device management and monitoring of individual units are performed by using a computer network connecting on control LAN or WAN interfaces of the CUJ. Interfaces are of the FE *IEEE 802.3* standard for speed up to 100Mbit/s. The CUJ device has implemented the Web Server which is used for management of the System for internal communication by using any computer with a standard Browser, independently, whose operative system is used on. Access to the device by using a computer is easy because it is not needed to install another software previously. To allow the proper connection via Ethernet, IP parameters for local computer and Central control unit have to be configured for the work in the same IP network. Also, to make the packaged data transmission in the system, every connection unit has to be in the same address range as IP address of the central control unit. After accessing

to the Web Browser, it is needed to login by entering a valid username and password. In this way, the authentication and authorization validation of the user operator are archived. Management and parameters of the System for internal communication monitoring are performed in this way. The graphical display allows the operator to easily assess the system information and configure parameters for the work for all the units of the System for internal communication. Using navigation pages, it is possible to make a reconfiguration and upgrade software which is one of the most important characteristics in modern telecommunication information technology.

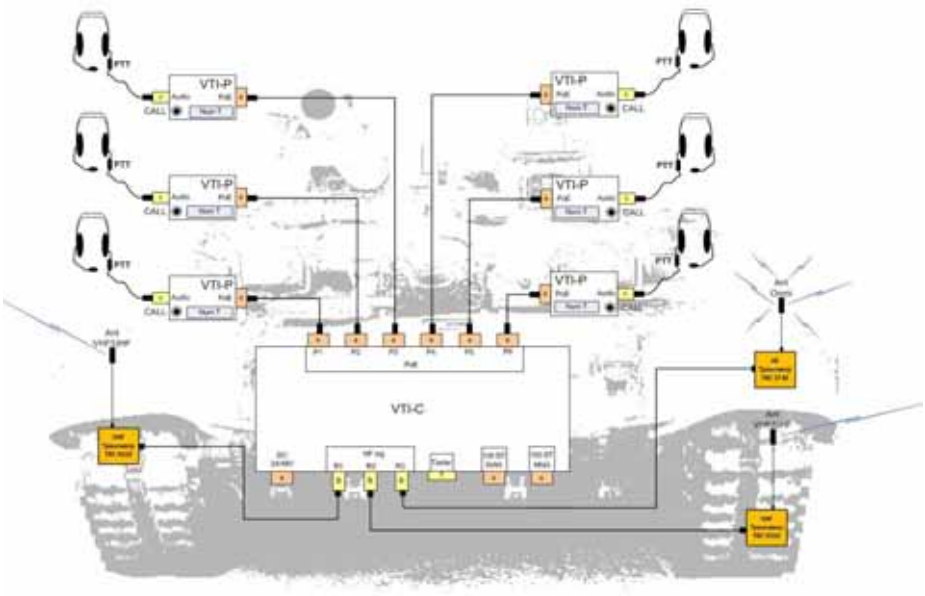


**Figure 6.** Integration system in battle armored vehicles

The protocol for communication between the computer and the device is standard HTTP. In this way, the IP addressability and ability to connect in the LAN vehicles are archived. Connecting the System for internal communication on telecommunication information subsystem of the vehicle is realized by using a control manage IP Switch, so it is possible to connect more than one combat vehicle. With the right configuration and adjustment of the static route, parameters and gateway address of the switch and other devices in the vehicle, it is possible to share the resources between the vehicles that are in different address network. Also, it is possible to share the radio resources between the connected vehicles by using the System for internal communication.

## Climatic and mechanical conditions of use of the system

In terms of mechanical durability every unit of the System for internal communication considers the SORS 5706/84 standard, i.e. all units of the device are made in K – 2 class. All connection with the devices are accomplished with cylindrical military connectors which are also made in K – 2 class, i.e. connectors are adjusted for the use in tactical conditions. The accommodation for Central control unit is realized in the working place of the command armored vehicle in amortization rack, while the accommodation for connection units is possible to be realized on non – amortization stand in front of the operator. Before the system was integrated in the vehicle, the laboratory tests of the device's resistance to the effects of vibration, device's resistance to the effects of quake and device's resistance to the effects of shock were performed. The laboratory testing of the device's resistance to the effects of vibration was realized in frequency range (10 – 55 Hz) according to the *Fc* test procedure, for six hours continuously. The laboratory testing of the device's resistance to the effects of quake was realized according to the *Eb* test procedure, with a force of 25g and with 4000 times repetition, while the laboratory testing of the device's resistance to shock was realized according to the *Ea* test procedure, with force of 50g and with 18 times repetition. In this way, the influence of the work environment is simulated and ability of the devices to work in mobile conditions of use without degradation functional and electric characteristics of the System for internal communication.

The System for internal communication is declared for use in conditions of higher and lower temperature of the working environment, and also the system is declared for working on elevated temperature with humidity. The operating ambient temperature in which the system functional can be used is within the range from -15$^{o}$C up to +55$^{o}$C, and humidity from 5% up to 95%, while the storage temperature is in the range from -40$^{o}$C up to +70$^{o}$C.

According to the results of the laboratory testing of the System for internal communication, it has been proven that the choice and quality of integrated electronics and other electromechanical components are suitable for military use.

## Electromagnetic compatibility

Electromagnetic compatibility establishes interface and associated verification requirements for the control of the electromagnetic interference (EMI) emission and susceptibility characteristics of electronic, electrical and electromechanical equipment and subsystems designed or procured for use by activities and agencies of the Department of Defense. Such equipment and subsystem as the System for internal communication may be used independently or as an integral part of other subsystems or systems such as combat, noncombat, command armored vehicles.

Testing characteristics of the electromagnetic compatibility included immunity to the electric field of electromagnetic interferences, conduction interferences and electric field of radiated interferences. All those tests were realized according to the Department of Defense of the Republic of Serbia (SORS) 1029/89 standard and the Department of Defense of the United States of America MIL-STD 461F standard.

Testing characteristics of immunity to the electric field of electromagnetic interference have been realized in Faraday's cage in the frequency range from 30 MHz to 990 MHz according to the SORS 1029/89 standard. The basic concern is to ensure that the System for internal communication will operate without degradation in the presence of electromagnetic fields generated by antenna transmissions and signal generator. Before the test, the ambient was calibrated to the given test field so that the electric field does not vary substantially over the pickup element. The excitation levels from the signal generator were determined so that the required strength of the interfering electric field of 5V/m could be achieved. That has been done with the help of RF amplifiers and emission antenna. Frequency overwriting was performed continuously with delay of 2 seconds on each tested frequency. While the system for internal communication was exposed to an external interfering electric field, during the measurements in horizontal and vertical polarization, there was no interruption of the voice signal which was sent through the system for internal communication. In this way it has been shown that the system for internal communication fully meets the characteristics of ips2 test procedure of the SORS standard.

Testing characteristics of the conduction interferences have been performed according to the SORS 1029/89 standard. The test procedure is used to verify that electromagnetic emissions from the system for internal communication do not exceed the specified requirements for power input leads, including returns. So, it is needed to obtain a power for the device from other sources which is not a part of the system for internal communication. The test has been realized with current probes which were placed around plus and minus half of the conductor respectfully. The measurement results are graphically shown in Fig. 7 and in Fig.8. The graphics show the level of narrowband (upper graphic) and broadband (lower graphic) conduction interferences of the signal.

From Fig.7 it could be seen that the level of the useful signal is a little above the limit level so it can be concluded that the system for internal communication may have some interferences which could adversely affect the subsystems which are integrated in the vehicle. Also, this interference may have a negative effect on clarity and intelligibility of the voice communication between a crew member into the command armored vehicle. This exceedances of the signal level above the limit values are in the frequency range from 5.5MHz up to 8MHz, about 25MHz and about 50MHz. According to these values, it can be concluded that these disturbances can be encouraged from PoE switch whose clock signal operates at 5MHz and its amplified harmonics. This problem has been solved by installing an appropriate filter and the measuring test has been repeated. The attenuation characteristic of the built-in filter is shown in Figure 9. For this type of interferences in this frequency range, the component that has the best attenuation characteristic is EMI/RFI PI Filter 8.2nF.

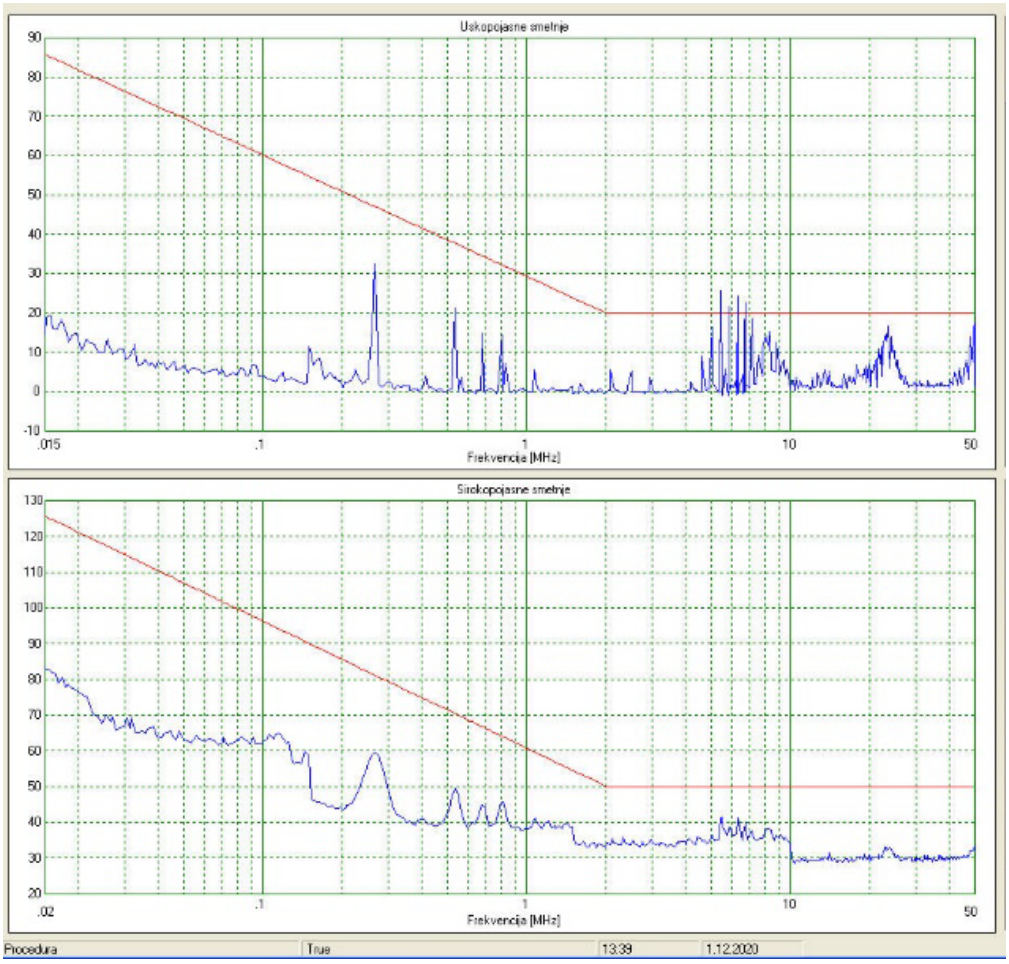


**Figure 7.** Diagram of EM conduction interferences (plus node)

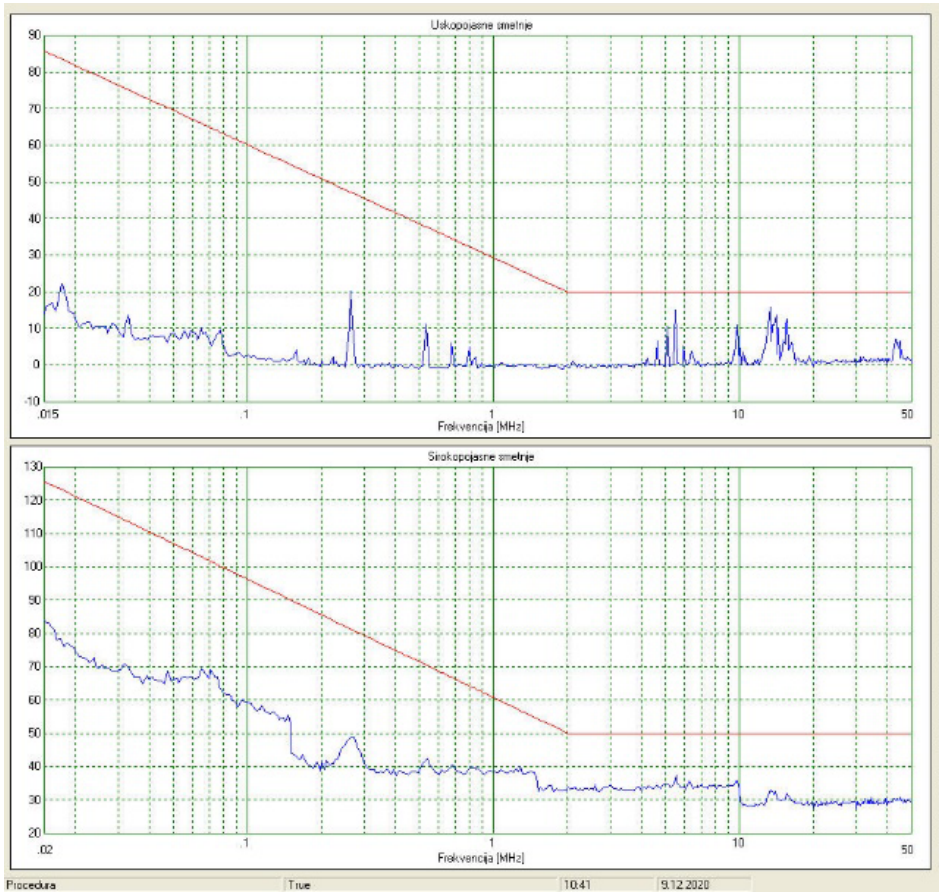


**Figure 8.** Diagram of EM conduction interferences (plus node) with integrated filter

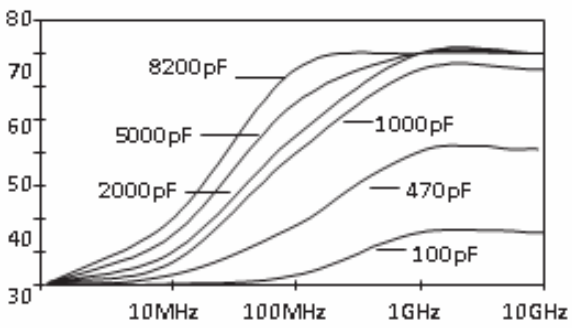


**Figure 9.** Filter data

From graphics in Fig.7 and Fig.8 it can be concluded that after installing the filter, all components of the interferences are repressed. In Fig.8 it can be seen that there is no exceeding of the set limits and that the system for internal communication completely meets the characteristics of ks2 test procedure of the SORS standard.

Testing characteristics of the electric field of radiated emissions' interferences was performed according to the SORS 1029/89 standard. The test was realized in the Faraday's cage in the frequency range from 14kHz up to 10GHz. The test procedure is used to verify the electric field of radiated emissions from the system for internal communication and its associated cabling does not exceeed specified requirements. The tests were performed with the appropriate test antennas: rod and ultra-log antenna. First, it measured the ambient interferences for horizontal and vertical polarization in order to obtain the most accurate results. The calibrated signal level of the ambient must be at least 6dB below the limit value so the test procedure could be performed.

The receiver antennas are placed at a distance of 1m from the front edge of the device and 120cm above the floor ground plane. The active conference settings were within the system for internal communication. Detectors of high and medium power of the measuring receiver recorded the levels of the electric field of interferences, which determined the criterion for discrimination of narrowband and broadband interference of 6dB. The measurement results are graphically shown in Fig.10 and in Fig.11. The limit values are shown with red color. From the attached it can be concluded that after installing the filter, all components of the interferences are repressed. In Fig.11 it can be seen that there is no exceeding of the set limits so the system for internal communication completely meets the characteristics of ps2 test procedure of the SORS standard.

In purpose to get the most precise and accurate results, testing characteristics of the electric field of radiated emissions' interferences of the system for internal communication was repeated according to MIL-STD 461F Ground Application, Navy Mobile & Army and MIL-STD 461F Ground Application, Navy Fixed & Air Force standard by using EMI receiver. The test was realized in the frequency range from 14kHz up to 30MHz to determine if the radio devices and their operation could be degraded because it is necessary to provide compatibility of the system for internal communication with the devices and subsystem which are integrated into the combat armored vehicle.

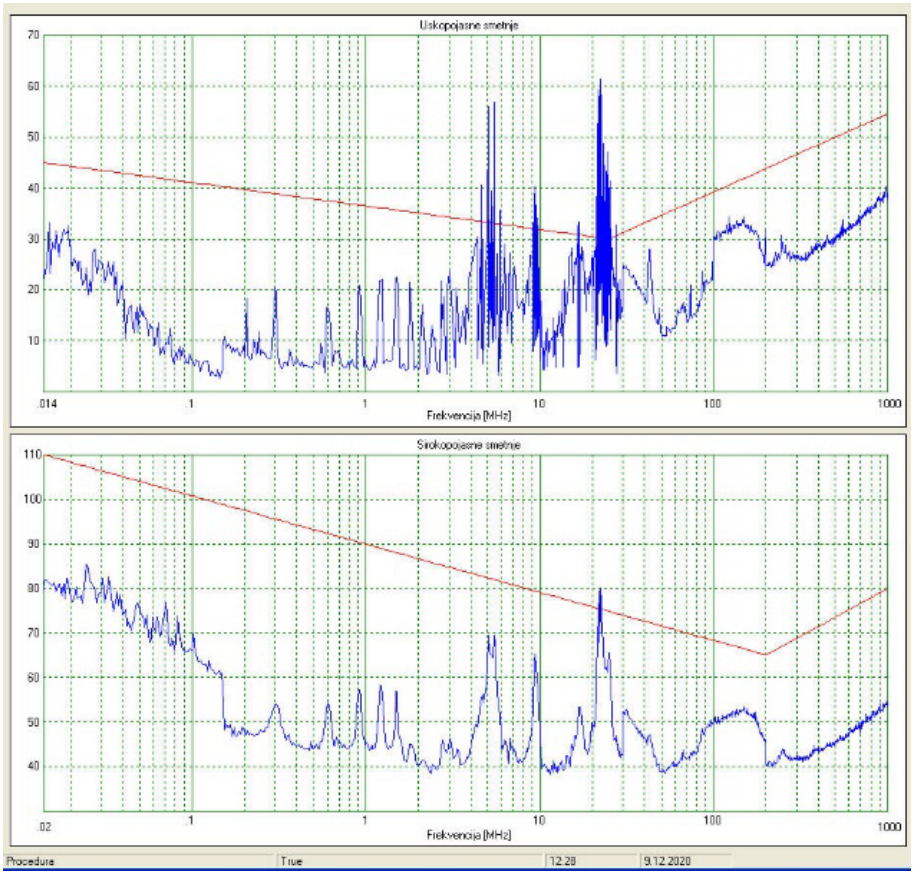


**Figure 10.** Diagram of electric field radiated emissions' interferences (vertical polarization)

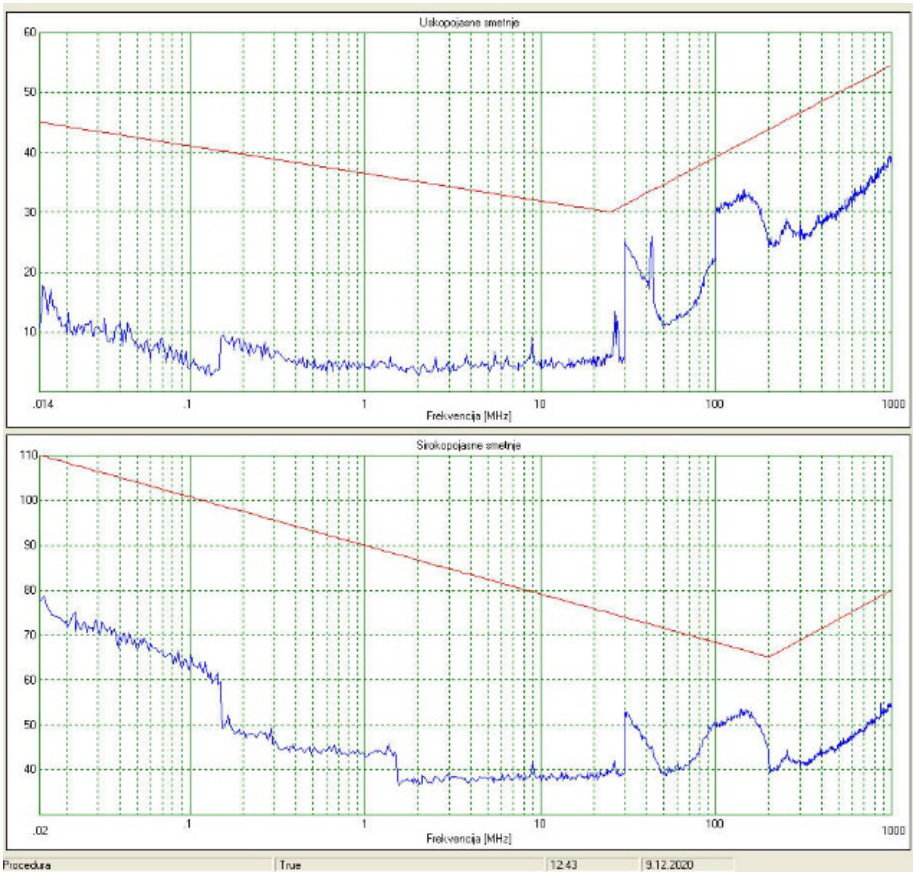


**Figure 11.** Diagram of electric field radiated emissions' interferences (vertical polarization) with integrated filter

In Fig.12 the permissible limit values which are marked with yellow dashed lines are shown. The level of the signal originating from the system for internal communication is also marked with yellow line. From the diagram it can be seen that the signal line is for more than 6dB lower than the line limit according to the MIL-STD 461F Ground Application, Navy Fixed & Air Force standard. These initial parameters have to be provided before starting any laboratory test so it would reduce the negative impact of the measurement environment.

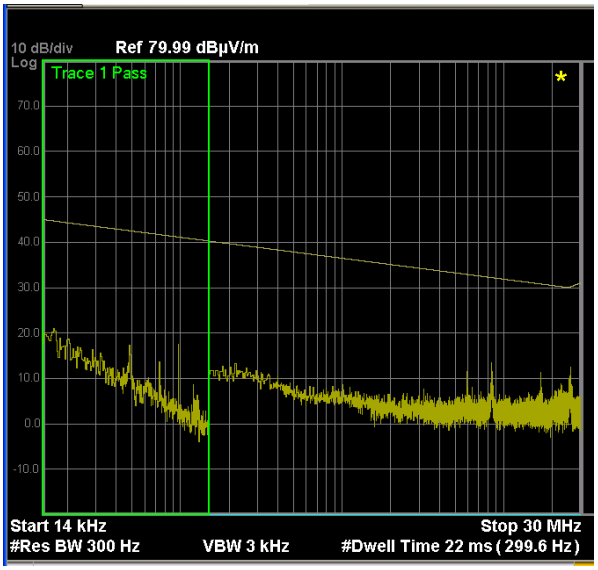


**Figure 12.** Diagram of electric field radiated emissions' interferences (vertical polarization) with EMI receiver

Analyzing the obtained results, it could be concluded that the system for internal communication meets the characteristics for electromagnet compatibility prescribed for the devices and systems for military conductions, use and operation according to both SORS 1029/89 and MIL-STD 461F standards.

## Conclusions remarks

Practical testing and examination in laboratory, whose results are partially presented in this paper, aim to describe the ability and how the System for internal communication works when it is integrated into combat armored vehicles.

Through the exploitation testing it was shown that this System for internal communication in noise places greatly facilitates work and voice communication between crew members in the vehicle. Next to the internal communication, crew members are provided with voice communication as well as sending data to higher and lower command level by using radio devices in VHF and HF frequency range. In this way, the level of operating is higher as well as response time to tactical request in real time from combat field, in any conditions of use, either in mobile or in stationary.

The technical and tactical requests were confirmed in the laboratory examinations whose requirements involved stricter conditions and standards which are used in military industry in relation to commercial use.

In terms of the applied technology, the System for internal communication belongs to modern devices with possibility of system expansion with additional functions and services. Every change, either hardware or software change, is possible to be realized on existing elements of the System for internal communication.

Next goal in future is the ability to realize a centralized supervision and management of the System for internal communication. One of the ways to apply this functionality would be that the device has an active link towards the appropriate server computers in which some applications would be installed. In this way the additional systematization, accessibility and working with the elements of the System for internal communication would be achieved, as well as the ability to manage the whole combat vehicle from the distance in which the device is integrated.

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# Sistem za internu komunikaciju i integracija u vojno taktičkim komunikacionim mrežama

**U ovom radu predstavljen je Sistem za internu komunikaciju i opisan je način na koji je ostvarena funkcionalna kompatibilnost uređaja sa ugrađenim podsistemima unutar vozila. U ovom radu opisan je uticaj različitih tipova elektromagnetnih smetnji na rad uređaja kao i potencijalno rešenje problema. Analizom dobijenih rezultata kao i funkcionalnim proverama za cilj imaju prikaz savremenosti, perspektive kao i sposobnost uređaja da zadovolji sve strože zahteve u budućim različitim i heterogenim mrežnim tehnologijama. Raznovrsnost i složenost upravljanja ovim uređajem su glavni vodeći faktori u razvoju i poboljšanju vojnih komunikaconih mreža čime se obezbeđuje kontrola ne samo domena**

**baziranih na paketima, već se postiže smanjenje kašnjenja prilikom prenosa govora i podataka a povećava se brzina odgovora na borbene zahteve u realnom vremenu. U ovom radu pokazane su metode i tehnologije kao i mogućnost primene uređaja u vojnom uslovima kao i mogućnost povezivanja različitih tipa mreža i uređaja.**

Ključne reči: **oklopno vozilo, CUJ, EMK, šlemofon, PJ, radio uređaji, UK-8, VVF i VF frekvencijski opseg, VoIP tehnologija, WEB server.**