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Choice and analysis of the anti-tank guided missile interface optimal solution

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This paper describes the design and functional parts of the second generation anti-tank guided missile. The detailed analysis of the missile interface is made with respect to the structural parts and their function. Also, all of the connectors, the connections and the cabling form of interface are presented in detail. The analysis comprises a detailed presentation of all signals which are transmitted by the interface during the sequence of the missile launching and its flight towards the target. The criteria for the interface optimization estimation are given, as well as the methods for its main characteristics verification.

Key words: **anti-tank missile, guided missile, micro-cable guidance, interface, connector, block scheme**

Notation and symbols

APC	- armoured personnel carrier
ARM11	- arming position of the SAM1
ARM22	- arming position of the SAM2
ATGM	- anti-tank guided missile
BE	- block of electronics
BRM	- booster rocket motor
BRMI	- booster rocket motor ignition
CC	- contact cap
CF	- contact foil
CFS	- signal after the contact foil break
CLU	- command and launch unit
COM	- bipolar command signal
D	- "45°" signal from gyroscope
D32	- signal after 32 D-signals obtained
EI	- electrical initiator
EI11	- electrical initiator of the fuse for the first safety position of the SAM1
EI12	- electrical initiator of the fuse for the second safety position of the SAM1
EI21	- electrical initiator of the fuse for the first safety position of the SAM2
EI22	- electrical initiator of the fuse for the second safety position of the SAM2
EDD11	- double action electrical detonator in the SAM1
EDD22	- double action electrical detonator in the SAM2
EMI	- electro-magnetic interferences
ERA	- explosive reactive armour
F	- flare
G	- gyroscope
GND	- signal ground
GS	- gyroscope bipolar signal
ICG	- impulse command generator
IP1 and IP2	- ionization probes within WH1
IP1+IP2	- signal from IP1 and (or) IP2
IR	- infra-red
LB	- lithium batteries
L_{mnb}	- beginning of the TVC system actuator electro-magnet coil
L_{mne}	- end of the TVC system actuator electro-magnet coil
LT	- launching tube
MB	- missile electronical assembly mother board
MC	- micro-cable
MEA	- missile electronical assembly
MCRC	- micro-cable returning conductor
PCB	- printed circuit board
PTL	- pyrotechnic lock of the missile
SAM1	safe and arming mechanism of WH1
SAM2	- safe and arming mechanism of WH2
SRM	- sustainer rocket motor
SRMI	- sustainer rocket motor ignition
START	- start of the missile
$\overline{\text{START}}$	- inverted start signal
TB	- thermal battery
TBGI	- thermal battery and gyroscope ignition
THCW	- tandem hollow charge warhead
THCW BE	- THCW block of electronics
TVC	- thrust vector control
TVSINC	- signal for the flare synchronization and power supply
U_{C1}, U_{C2}	- unipolar command signals
V	- vertical signal from gyroscope
WH	- warhead
WH1	- auxiliary warhead
WH2	- main warhead
J_1	- CLU connector
J_2	- "umbilical" connector
J_3	- micro-cable connector
J_4	- lithium battery housing connection
J_5	- pyrotechnic lock connection

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J_6	- BRMI connection (Q_1)
J_7	- connection at the end of MC (Q_1)
J_8	- flare connection (Q_1)
J_9 , J_{10}	- connectors of the TVC left and right actuators (Q_2)
J_{11}	- SRMI connection (Q_3)
J_{12}, J_{13}	- THCW electronic assembly micro-connectors (Q_4)
J_{14}	- MC CF connection
$Q_1, Q_2, Q_3 \, i Q_4$	- missile interface stripe cables

Introduction

THE ATGM is a WH transporter from the launching site to the target, which has to be either destroyed or disabled for combat activities. The ATGM is intended for fighting the enemy tanks with or without ERA, as well as APCs, of all generations. For the destruction of tanks equipped with ERA, the THCW is in use.

The target identification and selection has to be done prior to launching. For the second generation ATGM guidance, described in this paper, the CLU is exploited. The CLU, during the flight, sends the command signals towards the missile via communication link launcher-missile. The missile is guided to the line of sight defined by the gunner while aiming the target, from various combat positions. The CLU could be used for launching and guidance of several ATGMs. Their number is restricted by the CLU and the gunner survival time during combat. Because of that, the second generation ATGMs design and technological level are less complex than those immanent to the third generation ATGMs, working on the bases of “fire and forget” principle, using homing heads.

Design and functional parts of the missile

The ATGM general design is shown in Fig.1, [1].

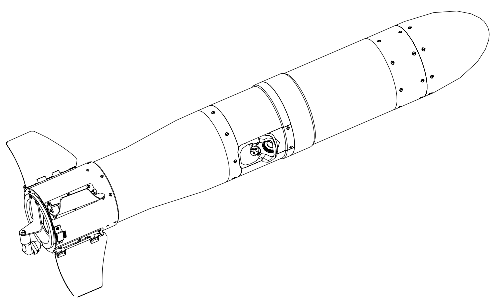

Figure 1. ATGM

The missile main functional parts, shown in Fig.2, are:

The front section, which comprises:

- TB, for the missile electrical power supply.
- G, for the measurement of the missile angular position and velocity around the axial axis.
- MEA, for the missile functions control.
- WH1 with SAM1, for the ERA destruction.
- CC assembly, for the THCW activation.

The SRM section, with TVC for the missile propulsion and control.

The main WH section, with SAM2 for the tank main armour penetration.

The aft section, which comprises:

- BRM, which gives the initial velocity and rotation to the missile and completes the burning within the LT.
- IR flare, which enables the CLU to see and guide a missile towards the target.
- Spool with micro-cable, which acts as the communication link for the command signals’ transmission between the launcher and the missile, during the flight.
- Four wings, for the missile stabilization and rotation during the flight.

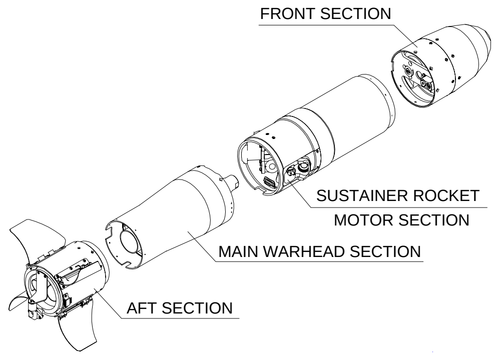

Figure 2. Functional parts of the missile

The MEA, in functional sense, is composed of the electronical blocks intended for:

- SRM ignition, at the distance which is safe for the gunner and launcher.
- TVC system control, in order for the commands to be executed according to the command signals sent by the CLU, via MC, towards the missile.
- Generating, forming and sending the signals from the G to the CLU, via MC.
- The MC interface at the MEA, for realization of the bilateral communication between the missile and the CLU.
- The IR flare operation control on the working frequency synchronized with the CLU coordinator.
- The SAM1 and SAM2 control, in order for the securing, arming and synchronizing of the THCW action at the target.

Missile interface

The missile interface connects MEA with CLU and integrates the missile elements with MEA into uniform functional entity, Fig.3. The CLU, using J_1, J_2, J_3 and the LT interface, controls the launching sequence and guides the missile towards the target, [2].

The missile interface is composed of:

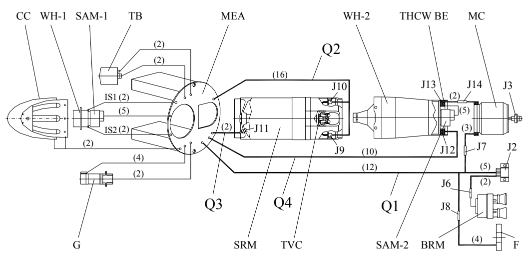

Figure 3. Missile elements and interface

1. The stripe cabling set Q_1, Q_2, Q_3 and Q_4, Fig.3, which are firmly connected (soldered) to the MEA's MB on one end, and on the other ending in connectors or contacting attachments, Fig.4.

2. The interfaces of CC, WH1, SAM1, TB and G, together with the MEA's MB, onto which they are soldered.

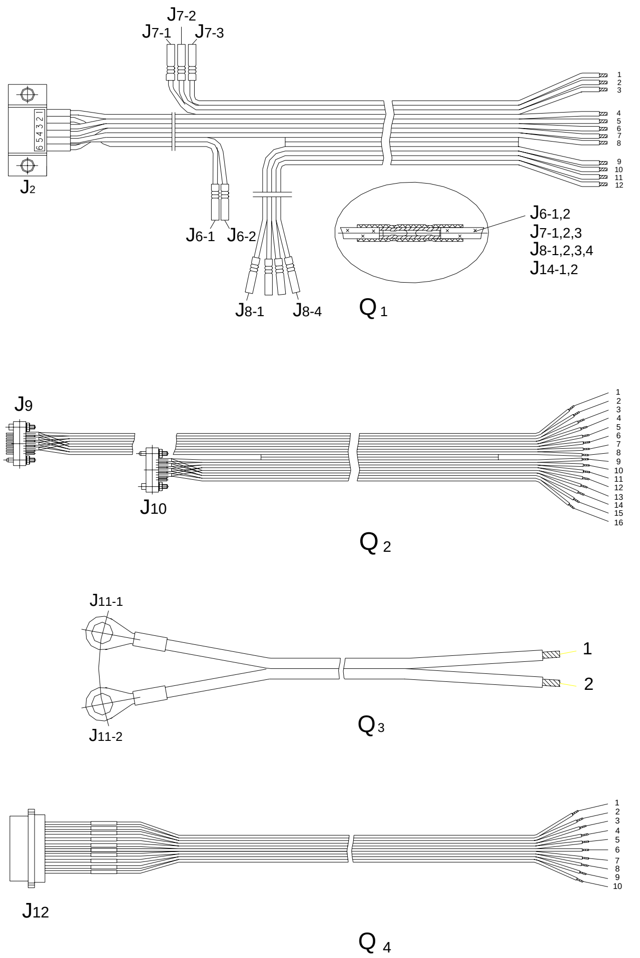

Figure 4. Missile interface

The Q_1 has 14 conductors and connects MEA's MB with CLU, MC and F via J_2, J_7 and J_8 respectively, and the CLU with the BRM igniter via J_2 and J_6, Fig.3.

J_6, J_7, J_8, and J_{14} are the contacting attachments realized by contacting cases, Fig.4. The conductors' connection is obtained by crimping of both ends of the contacting case using a special tool able to control the force of deformation depending on the conductor diameter. From the outside, contacting cases are electrically isolated. J_2 is directly connected with MEA's MB by 5 Q_1 conductors. J_3 is placed at the MC beginning and J_7 is placed at the MC end. J_7 is directly connected with MEA's MB by 3 Q_1 conductors, and has three contacting cases. The F is directly connected with MEA's MB via J_8 and *4* Q_1 conductors. J_8 has four contacting cases. The BRM is directly connected with J_2 and the CLU via J_6 and 2 Q_1 conductors. J_6 has two contacting cases.

Q_2 has 16 conductors and connects MEA's MB with the TVC system actuators on both nozzles of SRM, via connectors J_9 and J_{10}, Fig.3 J_9 and J_{10} are the same connection pair with 14 contacts, Fig.4 J_9 on Q_2 is the "male" half-part of the connector, and J_{10} on Q_2 is the "female" half-part of the connector. It was made in such a way in order to avoid the mistake of crossing the connections between the left and the right actuator with Q_2.

Q_3 has two conductors and connects the MEA with the SRM igniter via J_{11}, Fig.3 J_{11} has two connecting pedals, Fig.4, which, by the nuts, have to tighten the screws on the SRM igniter contacts.

Q_4 has ten conductors and, by the "male" half-part of J_{12}, connects the MEA's MB with THCW BE, which controls the SAM1 and the SAM2 operation in order to secure and activate WH1 and WH2 within the THCW subsystem, Fig.4. The THCW BE is within a separate housing close to SAM2, which comprises the "female" half-parts of the J_{12} and J_{13} connectors. SAM2 is, by five conductors and by "male" half-part of the J_3, connected with the THCW BE. Two conductors of the J_{13} "male" half-part, connect CF of MC with the THCW BE, using J_{14}, Fig.3. The CC interface with the MEA's MB has two conductors, Fig.3. CC is further connected to the THCW BE, via Q_4. The CC has the switching function at the moment when the impact to the target occurs. Then, it is closed and activates WH1.

The SAM1 interface with the MEA's MB has five conductors, Fig.3. SAM1 is further in connection with the THCW BE, via Q_4. In that way, the SAM1 secures and activates WH1, when CC is switched on.

IS1 and IS2 are two coaxial cables, ending on one side, in a BNC connector, are connected with WH1, and on the other side are connected with the MEA MB, Fig.3. Using Q_4, IS1 and IS2 are further connected to the THCW BE. When WH1 is activated, then the ionization effect of explosion causes the short circuits in IS1 and IS2, thus generating the signal IS1+IS2, which activates the action delay and WH2 self-destruction delay lines within the THCW BE. IS1 and IS2 are in parallel connection on the MEA MB for the sake of higher reliability, because IS1+IS2 signal is generated when IS1 and (or) IS2 are in short circuit.

The TB interface with the MEA's MB has 2+2 conductors, Fig.3. Two of them are intended for TB ignition, and, via Q_1 and J_1, they are further connected with the CLU. The other two conductors are for the MEA power supply from TB. At the same time, they, via Q_1 and J_2, send the 42V control voltage towards the CLU as information that the TB has achieved its working mode.

The G interface with the MEA's MB has 2+4 conductors, Fig.3. Two of them are intended for the G gas generator ignition, and, via Q_1 and J_2, they are further connected with the CLU. The other four conductors bring the 15V voltage and V and D signals, from the G sensors, to the MEA's MB. The returning conductors GND for all of the signals are jointed into a single junction point at the MEA's MB and connected with the missile mass and the LT interface protective shield, using $J_{2\text{-}6}$, [3].

The interface and the electro-initiating elements (SAM1, SAM2, WH1, WH2, SRM, BRM, TB, G) are situated within the missile which has the characteristics of electrostatic protective shield against EMI, because the missile body is made of aluminium protected by the electro conductive surface cover. Due to that, the missile interface conductors are not shielded. The interface part (Q_1, Q_2, Q_4), which lies on the missile outside surface, is protected by the aluminium foil which has an electrical contact with the missile. Using $J_{2\text{-}6}$, the missile is connected with the LT interface protective electrical shield, [3].

The missile interface conductor cross-section diameter is determined with respect to the current intensity running through them (10A through the TVC system actuators during the impulsive regime of operation) and in order to minimize the length of conductors and the missile mass.

This interface has satisfied criteria adopted for the solution optimization evaluation: EMI protection, minimal number of the interface conductors, sockets and connectors and the minimal number of contacts in each of the connectors.

Interface functions

The CLU controls the missile launching sequence via J_2, [2]. The TBGI signal, using J_{2-1} and J_{2-6}, Q_1 and the MEA's MB, is transmitted to the TB and G igniters, Fig.5. The TB exit voltage of + 42V is transmitted to the CLU, using the MEA's MB, Q_1, J_{2-4} and J_{2-6}. This signal is feedback information that TB has achieved its operational mode and, consequently, the launching sequence can go on, [2]. On the other hand, the TB voltage is, directly and with the help of DC/DC converters, used for power supply of the MEA electronics (PCB1, PCB2 and PCB3), the G, the F (J_{8-2} and J_{8-3}) and the THCW electronics (J_{12-7}) with voltages of + 42V, + 15V and - 15V, Fig.5. The CLU is sending TVSINC signal to F, using J_{2-3} and J_{2-6}, Q_1, MEA's MB and finally via J_{8-1}, while the missile is in the LT, [3]. TB takes over the F power supply from LB on the LT, when the missile starts.

The gyroscope generates the signals V and D and sends them, in the form of bipolar signal GS (V+D), to the CLU, exploiting the MC interface (PCB3) and J_{7-2} and J_{3-2}. Signal D is also driven into the SRMI controller (PCB3), Fig.5.

Then, the CLU activates PTL, and when the information about PTL unlocking is received, the CLU ignites BRM exploiting the BRMI signal transmitted via exploiting the BRMI signal transmitted via J_{2-2}, J_{2-6} and J_6, Fig.5, [3].

When the missile starts the motion along the LT, J_2 disconnects and so does the short circuit between J_{2-5} and J_{2-6}, generating in that way the START signal driven via Q_1 to the MEA's MB. From MB, the START signal is driven to the SRM igniter controller (PCB3), and as an inverted signal $\overline{\text{START}}$, it is driven to the TVC system actuator controllers (PCB1 and PCB2) and via J_{12-9} to the THCW electronic block. The $\overline{\text{START}}$ signal holds the TVC system interceptors in the extreme position out of nozzles, till the moment of the SRM ignition and the first command appearance. Also, that signal activates the SRM ignition delay line and initiates the sequence of the THCW fuses arming, [2].

The SRM is ignited by the SRMI signal from the igniter controller (PCB3), which is sent to the SRM via MEA MB, Q_3 and J_{11}. The SRMI signal is generated 230 ms after the START signal and eight D signals, generated by the G, after the first missile rotation.

The only connection between the CLU and the missile, after the launching, is via J_2 and MC. The CLU guides the missile in flight by the command signals generated by the CLU ICG. The COM signals are calculated on the bases of the missile angular deviation from the line of sight, measured by the CLU coordinator, and on the bases of the missile angular position, measured by the gyroscope, [4]. The CLU sends a bipolar signal COM ($U_{C_1} + U_{C_2}$) via J_{3-1} (at the MC beginning) and J_{7-1} (at the MC end) towards

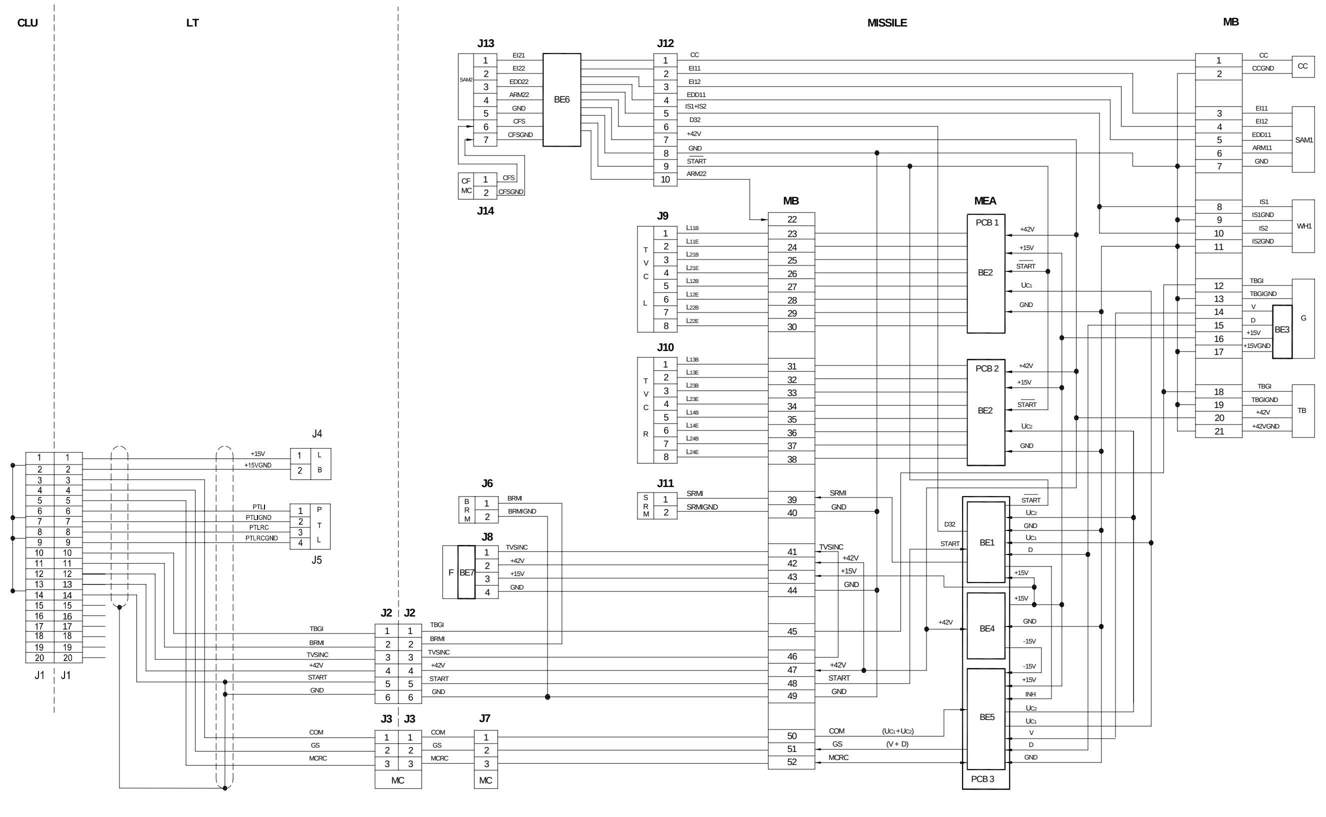

Figure 5. Missile and launcher interface electrical scheme

MEA's MB and the MC interface (PCB3), in direction opposite to the GS, Fig.5. Within the MC interface (PCB3), the COM signal is discomposed onto the U_{C_1} and U_{C_2}. Those signals are transmitted, using controllers TVC1 and TVC2, (PCB1 and PCB2), Q_2, J_9 and J_{10} to the TVC system actuators located on the left and on the right SRM nozzle, where the commands have to be executed. Each actuator has four electro-magnets where the places where their coils start are denoted by L_{mnb}, and the ends of their coils are denoted by L_{mne}, at the J_9 and J_{10}, [5] and [6].

The THCW BE controls the sequence of the SAM1 and the SAM2 arming and the WH1 and the WH2 synchronization while acting on the target. The SAM1 and SAM2 have two degrees of security, before arming, [2]. In the safe position, EDD11 and EDD21 in SAM1 and SAM2 are positioned out of the WH1 and the WH2 axes and are not able to activate them. During the arming process, the rotors, on which EDD11 and EDD22 are located, have to pass two steps that correspond taking off of two degrees of SAM's security. The first security degree is taken off when J_2 is separated and signal $\overline{\text{START}}$ is generated, while the missile has to achieve acceleration of 100 m/s^2 within LT. The signal $\overline{\text{START}}$ (J_{12-9}), enables the ignition of EI11 and EI21, via J_{12-2} and J_{13-1}, which enables the rotors in SAM1 and SAM2 to pass the way to the second secure position. For the second security degree taking off, it is necessary to generate signal CFS, at the moment when MC tears CF at the distance of 25m from the LT, and signal D32, at the moment when missile makes four rotations and 32 D impulses are generated. In the THCW BE, the CFS signal is introduced by J_{14-1}, J_{14-2} and J_{13-6}, J_{13-7}, and D32 signal by J_{12-6}, Fig.5. Those signals enable the ignition of EI12 and EI22, via J_{12-3} and J_{13-2}, thus making rotors free to place EDD11 and EDD22 into the WH1 and the WH2 axes. The SAM1 and the SAM2 arming is completed. Their status is controlled on the MEA's MB, in points ARM11 (6) and ARM22 (22), Fig.5. The contact ARM22 is transmitted from SAM2 to MEA's MB via J_{13-4}, THCW BE and J_{12-10}, while the contact ARM11 is transmitted directly from SAM1. In the safe position, the contacts ARM11 and ARM22 are shorted to the GND, while they are opened in armed position.

At the target, the CC is switched on and, via J_{12-1}, gives the information to the THCW BE to activate EDD11 in WH1, via J_{12-4}. The ionization effect of the WH1 explosion shorts the IS1 and IS2 thus generating signal IS1+IS2, which via J_{12-5}, activates the lines, for the WH2 action delay and self-destruction, in the THCW BE. 150 μs (maximum 200 μs) after WH1 explosion, EDD22 and WH2 must be activated via J_{13-3}. In that way, the sequence of events during the missile flight is finished.

Interface characteristics

The missile interface main characteristics, similar to the LT interface case, [3], are:

1. **EMI characteristics** in the sense of immunity and permitted emissivity which do not violate the function or degrade the characteristics of the other system components. Influenced by the EMI, the currents induced in the igniting circuits of TB, G gas-generator, BRM, SRM, SAM1, SAM2, WH1 and WH2 must be kept at the values lower than those which can activate electrical detonators and cause incidental ignition. For every single type of electrical detonator, the current intensity by which a detonator must not to be activated and intensity by which it must to be activated are defined in advance. The ATGM comprises the EMI sources such as the short impulses during the TB, gyroscope gas generator, BRM, SRM, SAM1 and SAM2 igniters' activation or the TVC system operation. Those EMI sources are not strong enough to activate electrical detonators in the neighbouring ignition circuits. For EMI protection, the major importance has to be concerned with the missile external surface protection from the electro conductivity point of view. The EMI characteristics are tested in accordance with the MIL standards 461 and 462.
2. **Electrostatic discharge immunity** during the handling and transportation is related to the electrical detonators activation prevention in adequate igniting circuits and to degradation or failure of semi conductive components within the MEA. Like in the previous case, the most important in this case are the electrical shielding of the interface and conductive protection of the missile body. The current induced by the gunner electrostatic discharge, while handling the missile within LT, is simulated by the 5pF condenser discharge through the 5KΩ resistor in the electrical detonator, charged under the 30 KV voltage. The current induced by the electrostatic discharge during the missile transportation by the helicopter, is simulated by the 100pF condenser discharge in the electrical detonator circuit, charged under the 300KV voltage.
3. **Isolation resistance** between the neighbouring conductors, of the every interface set, must be greater than 50MΩ, during the 500V direct test voltage implementation.
4. **Dialectical strength** of the every interface set is checked on the control panel. During the 650V alternative test voltage of 1 KHz frequency implementation, for 1s of duration, the penetration and the spark jump between the interface neighbouring conductors are not allowed.
5. **Interface functional characteristics** are approved on the control panel which has to indicate the short circuit or crossing between conductors, as well as the connection breaking.
6. **Interface dimensional characteristics** in reference to the conductors' length and cross-section diameter, are controlled by connecting all of the interface connectors and contacts to the appropriate positions on the missile. For this purpose, the missile acts as a control tool.

Conclusion

The ATGM is a WH transporter from the launching site to the target, which has to be either destroyed or disabled for combat activities. The missile main functional parts are: the front section, the SRM section, the main WH section and the aft section. In functional sense, the MEA is composed of electronical blocks intended for: the SRM igniting, the TVC system control, generating and sending the signals from the G to the CLU via MC, the MC interface at the MEA, the IR F operation control and synchronization and the SAM1 and the SAM2 control in order for securing, arming and synchronizing of the THCW action against the target.

The missile interface connects MEA with CLU and integrates the missile elements with MEA into uniform functional entity. The CLU, using J_1, J_2, J_3, and the LT interface, controls the missile launching sequence and guides it towards the target.

The missile interface is composed of: the stripe cabling set Q_1, Q_2, Q_3 and Q_4 soldered to the MEA's MB and the interfaces of CC, WH1, SAM1, TB and G, to the MEA's MB, onto which, they are soldered.

The interface and the electro-detonating elements are settled within the missile, which has the feature of the electrostatic shield against EMI, because it is made of aluminium, protected with electro-conductive surface protection. Because of that, the missile interface conductors are not shielded. The interface part (Q_1, Q_2, Q_4), which is laid onto the missile outside surface, is protected by the aluminium foil which has an electrical contact with the missile. The missile is connected with the LT interface electrical shield.

The interface, described here, has satisfied criteria adopted for the solution optimization evaluation: EMI protection, minimal number of the interface conductors, sockets and connectors, and minimal number of contacts in each of the connector.

The missile interface main characteristics identified by the appropriate measurement methods are: the EMI characteristics in the sense of immunity and permitted emissivity, electrostatic discharge immunity during the handling and transportation, isolation resistance and dielectical strength between the neighbouring conductors and their dimensional characteristics in reference to the length and cross-section diameter.

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Izbor i analiza opitmalnog rešenja interfejsa protivoklopne vođene rakete

Prikazana je konstrukcija i funkcionalne celine jednog rešenja protivoklopne vođene rakete 2. generacije. Izvršena je detaljna analiza interfejsa rakete sa aspekta sastavnih elemenata i njihove funkcije. Detaljno su prikazani svi konektori i kontaktni priključci, kao i kablovska forma interfejsa. Detaljno su prikazani svi signali koje interfejs prenosi u toku sekvence lansiranja i leta rakete do cilja.Dati su kriterijumi za procenu optimalnosti rešenja i metode za ispitivanje osnovnih karakteristika interfejsa.

Ključne reči: **Protivoklopna raketa, vođena raketa, vođenje pomoću mikrokabla, interfejs, konektor, blok šema.**

Выбор и анализ оптимального решения интерфейса противобронированной управляемой ракеты

В настоящей работе показана конструкция и функциональные части одной противобронированной управляемой ракеты 2-ой генерации. Со стороны составных элементов и их функции сделан подробный анализ интерфейса управляемой ракеты. Здесь подробно показаны все штепсельные разъёмы и соединители, а в том числе и кабельный интерфейс. Здесь тоже подробно показаны все сигналы, которые интерфейс передаёт в течении последовательности запуска и полёта ракеты до цели. Здесь приведены критерии для оценки оптимальности решения и методы для исследования основных характеристик интерфейса.

Ключевые слова: **противобронированная ракета, управляемая ракета, управление при помощи микрокабеля, интерфейс, соединитель, блок-схема.**

Le choix et l'analyse de la solution optimale de l'interface du missile antichar guidé

Dans ce travail on a présenté la construction et l'ensemble fonctionnel de la solution d'un missile antichar guidé de la deuxième génération. Une analyse détaillée de l'interface de ce missile a été faite du point de vue de ses éléments structuraux et de ses fonctions. Tous les connecteurs, toutes les connections ainsi que la forme câble de l'interface sont présentés en détails.On a aussi démontré tous les signaux que l'interface transmet pendant la séquence du lancement et au cours du vol de missile jusqu'à son arrivée au but. On a donné les critères pour évaluer l'optimisation de la solution ainsi que les méthodes pour la vérification des caractéristiques principales de l'interface.

Mots clés: **missile anticlar, missile guidé, guidage par microcâble, interface, connecteur, schema bloc.**