Proximity Sensor vPS-M23 Functional Demo Software

Nemanja N. Deura
Metropolitan University, Software Engineering
Vlatacom Institute
Belgrade, Serbia
nemanja.deura.5335@metropolitan.ac.rs

Nikola Latinović
Vlatacom Institute
Belgrade, Serbia
nikola.latinovic@vlatacom.com

Predrag Petronijević
Vlatacom Institute
Belgrade, Serbia
predrag.petronijevic@vlatacom.com

Abstract— **Proximity sensor vPS-M23 is a device that was developed as an addition to the impact fuze vAF-M23 and which gives the fuze very important proximity function. Proximity sensor together with fuze vAF-M23 and initiator vFI-M23 form one system called proximity sensor kit vPSK-M23. This paper describes the design concept of the proximity sensor kit, the function of the proximity sensor, an overview of the basic characteristics of the sensor, an overview of the electronic components that make up such a device and an overview of the software used to check the functionality of the sensor.**

Keywords- proximity; sensor; software; vlatacom;

I. INTRODUCTION

Proximity fuzes are intended to detonate missiles/warheads automatically upon approach to target and at such a position along the flight path of the missile as to inflict maximum damage to the target. Various methods of obtaining proximity operation against a target were investigated: electrostatic, acoustic, optical, and radio. Prime considerations for a proximity fuze were reliability and simplicity. [1]

Among various possible types of radio proximity fuzes, an active-type fuzed operating on the doppler effect was selected as being the most promising method. [1]

The Doppler effect (Figure 1) is the phenomenon that, due to the relative movement of the receiver or source, the frequency of the wave changes. If the receiver and transmitter move toward each other, the frequency shifts up (rises), and if the receiver and transmitter move away from each other, the frequency shifts down (falls).

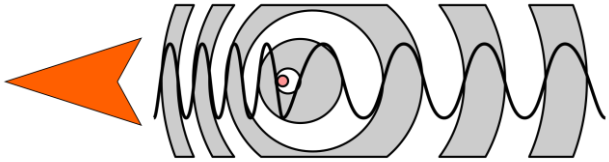

Figure 1. Doppler effect

In a doppler-type fuze, the actuating signal is produced by the wave reflected from a target moving with respect to the fuze. The frequency of the reflected wave differs from that of the transmitted wave, because of the relative velocity of the fuze and the target. The interference it creates with the transmitter results in a low-frequency beat caused by the combination of the transmitted and the reflected frequencies. The low-frequency signal can be used to trigger an electronic switch. Selective amplification of the low-frequency signal is generally necessary. [1]

For use against surface targets, proximity fuzes are designed for an optimum height of burst, depending on the nature of the target and the properties of the missile. These optimum heights vary from 10 to 70 ft for fragmentation and blast bombs and are of the order of a few hundred feet for chemical warfare bombs. [1]

Impact fuze detonates and losses more than 50% of its energy compared to the case if explosion takes place at certain height. Proximity fuze is used to enhance the performance of warhead explosion and increase the effective distance of fragmentation warhead (Figure 2). Optimum burst point varies according to the nature of the target and the properties of the ordnance itself. [2]

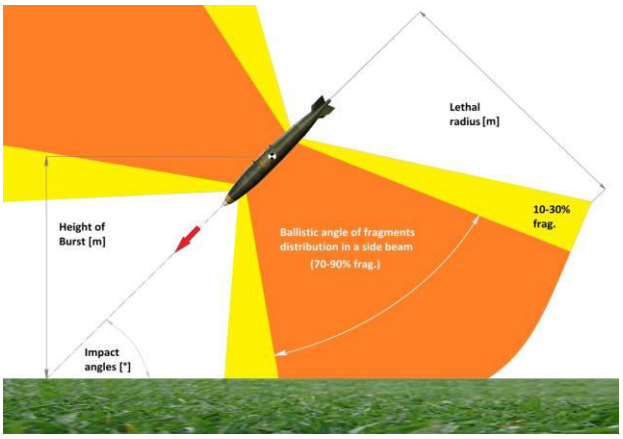

Figure 2. Path of fragments proximity fuze

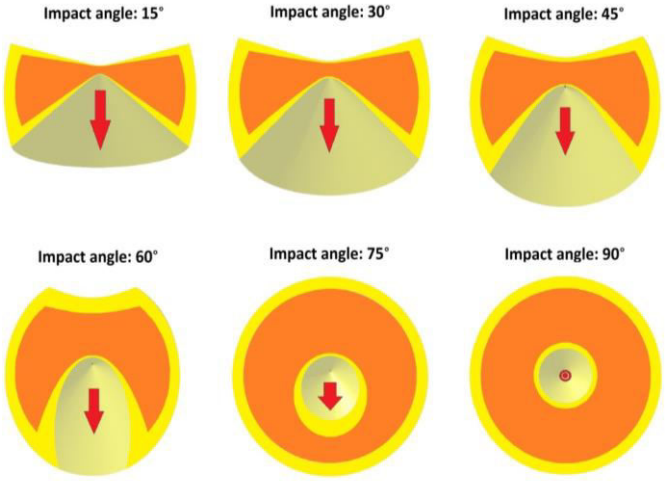

Figure 3. Appearance of lethal area for different impact angles

II. PROXIMITY SENSOR KIT VPSK-M23

Proximity sensor kit vPSK-M23 consists of proximity sensor vPS-M23, fuze vAF-M23 and initiator vFI-M23. The position of the system components is shown in Figure 4.

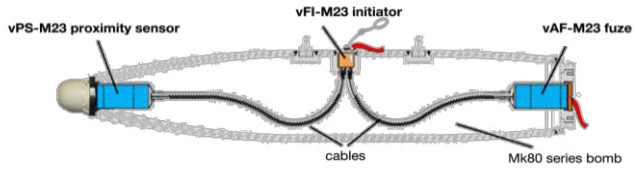

Figure 4. The position of the proximity sensor kit (vPSK-M23) elements inside the warhead

The Proximity Sensor vPS-M23 is intended for improving terminal effectiveness of aircraft general purpose bombs (fragmentation – blast) by providing low altitude proximity function. The sensor provides a proximity function for the MK 80 series general purpose bombs.

The warhead usually contains a powerful but relatively insensitive high explosive that can only be initiated by the heat and energy from a primary explosive. The primary explosive is a component of the fuze subsystem and is normally loaded in the detonator. If the detonator is designed properly, it can only be activated by a unique fire signal received from the target-sensing device. A detonator can be designed to activate when it receives either electrical energy (high voltage) or mechanical energy (shock or stab) from the target sensor. [3]

The proximity sensor is mounted on the front fuze well of the general purpose bomb. The sensor is connected with fuze vAF-M23, which is mounted at aft part of the warhead, by spiral cable via the initiator vFI-M23. Fuze vAF-M23, is a modified fuze vAF-M17 capable of accepting firing signal from vPS-M23 proximity sensor. Initiator vFI-M23 is a modified version of vFI-M17 initiator and has the capability to pass the firing signal from vPS-M23 proximity sensor to vAF-M23 fuze. The fuze vAF-M23 and initiator vFI-M23 are the universal version that can be used for impact and delay event without the proximity sensor and with proximity sensor for proximity event.

The fuze is a device that detonates a munition's explosive material under specified conditions. In addition, a fuze will have safety and arming mechanisms that protect users from premature or accidental detonation. The fuze may contain only the electronic or mechanical elements necessary to signal or actuate the detonator, but some fuzes contain a small amount of primary explosive to initiate the detonation. Fuzes for large explosive charges may include an explosive booster. [3] [4]

The Proximity Sensor vPS-M23 is battery operated, and equipped with RF Doppler radar proximity sensor that can operate in both low and high drag deliveries, and incorporates electronic counter measures (ECM) resistance.

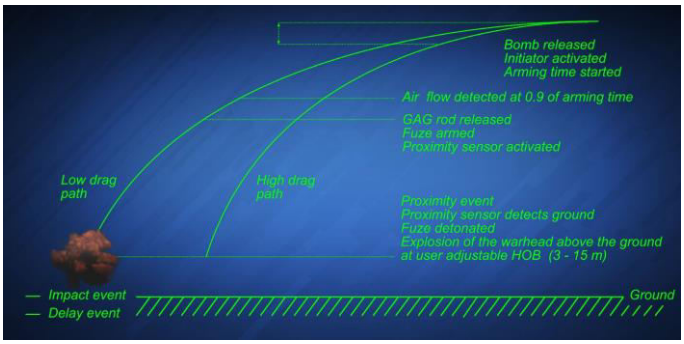

Figure 5. Proximity sensor kit function description

The Proximity Sensor vPS-M23 is initiated by a signal from the vFI-M23 initiator after the arming time is elapsed (Figure 6).

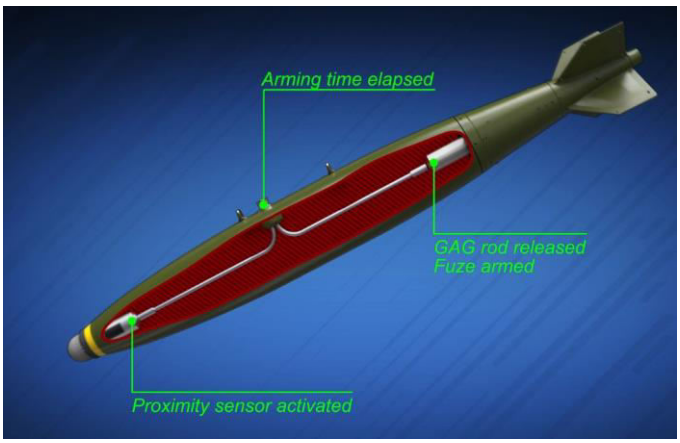

Figure 6. Proximity sensor receives signal from initiator

When the proximity sensor receives a signal from the initiator, it starts checking whether the distance to the target meets the previously set values of the HOB (Height of Burst) parameter. When this condition is met, the proximity sensor sends a signal to the fuze, which is then activated (Figure 7).

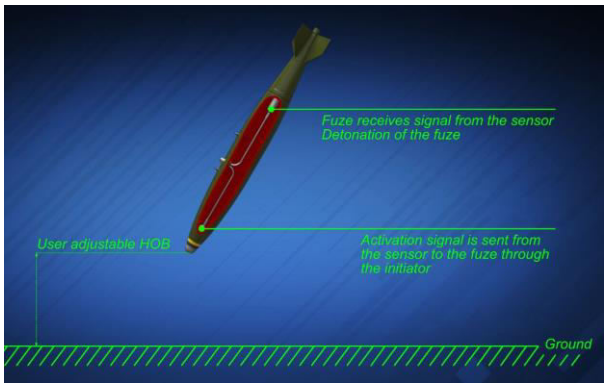

Figure 7. Proximity sensor sends signal to the fuze

III. PROXIMITY SENSOR VPS-M23 BASIC COMPONENTS AND PRINCIPLES

Housing of the proximity sensor is a mechanical assembly manufactured from aluminum and stainless steel that houses the electronic components. An exploded view of the proximity sensor is shown in Figure 8.

Basic principles of proximity sensors:

- Functioning principle FMCW radar (Frequency Modulated Continuous Wave) which provides range and velocity
- Low power Transmitter - Low Probability of Interception (LPI)
- Measurement target distance and velocity with high precision
- Inherently resistive to ECM (Electronic Counter Measures)
- Technology
    - Digital signal processing
    - Microwave electronics
    - Patch Antenna

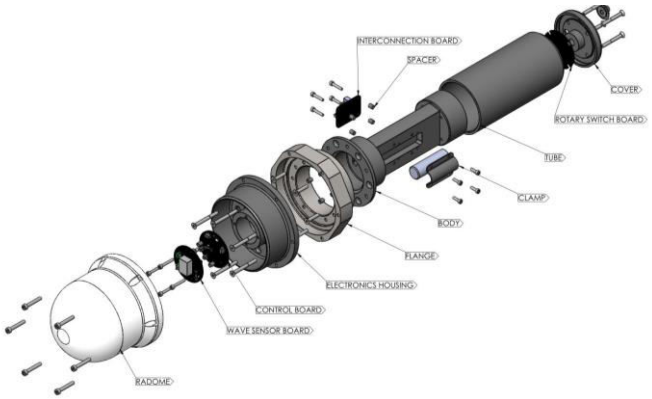

Figure 8. Proximity sensor vPS-M23 exploded view

Basic characteristics of proximity sensor:

- Based on FMCW Microwave radar sensor and powerful DSP processing.
- Patch PCB Antenna designed, simulated and tested according to specific pattern requirements.
- FMCW Microwave radar with quadrature mixer and IF signal conditioning.
- Signal processing board based on powerful Cortex M4 ARM with DSP capabilities. It generates Firing signal for vAF-M23 fuze.
- Possibility to add some parameter settings if needed
- Battery power supply

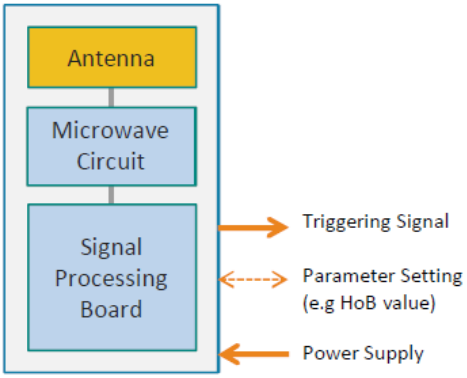

Figure 9. Proximity sensor vPS-M23 block diagram

IV. ELECTRONIC BLOCK OF THE PROXIMITY SENSOR VPST-M23 TEST (DEMO) VERSION

A special test version of the proximity sensor vPST-M23 was developed to validate the concept of design and this model is shown in Figure 10.

Figure 10. Proximity sensor vPST-M23

This version of the proximity sensor consists of 4 PCB electronic boards:

- Wave sensor board
- Control board

- Interconnection board
- Rotary switch board

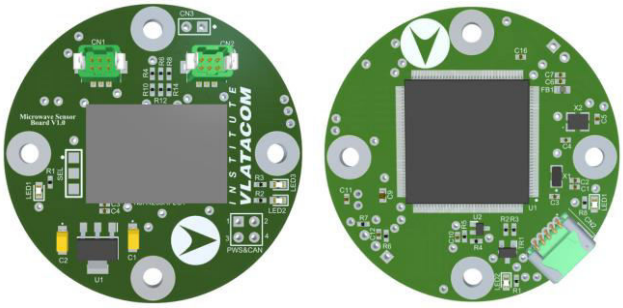

Figure 11. Wave sensor board and control board

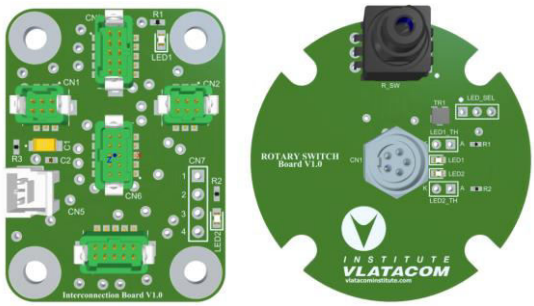

Figure 12. Interconnection board and rotary switch board

On the ***wave sensor board*** there is a sensor that enables the detection of the ground surface. The board contains a special linear voltage regulator for powering the sensor. Communication between the sensor board and the control board takes place using the UART protocol (interface), it also contains an LED indication when the sensor is activated. The sensor board is connected to the control board using a board to board connector.

The ***control board*** is used for processing signals from the sensors, as well as for complete control of the device. On this board there is a powerful Cortex M4 ARM that performs signal processing and gives the command to the vAF-M23 fuze for firing. The processor is programmed using the JTAG interface. Two UART protocols are implemented on the processor unit, one for the sensor unit and the other for communication with a PC. The wave sensor board and control board are shown in figure 11.

The ***interconnection board*** is a communication board that serves to transfer data from the rotary switch board to the control board and vice versa. Also, this board serves to distribute the power supply from the lithium ion battery.

There is a rotary switch on the ***rotary switch board***, which is used to set the corresponding HOB before placing it in the warhead, also on this board there is a connector that serves to communicate with the initiator and the fuze, that is, it serves for the proximity sensor to receive a signal from the initiator when to be activated (start) and for the proximity sensor to send a fire signal to the fuze when all conditions are met. On this board there is a connector for connecting to a computer, and there is an output for an external switch that is used to start the battery. The interconnection board and rotary switch board are shown in figure 12.

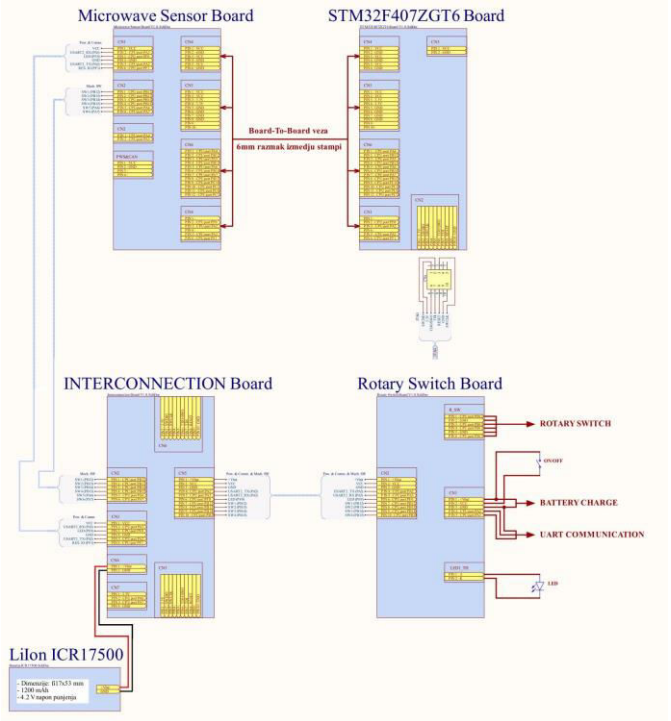

Figure 13. Electronic block diagram of the proximity sensor vPST-M23

The proximity sensor is powered by a *lithium-ion battery* that allows the device to be active for no less than 200 seconds after being released from the aircraft. This battery can be recharged using the connector on the rotary switch board.

V. PROXIMITY SENSOR VPST-M23 FUNCTIONAL DEMO SOFTWARE (VPST-M23 FDT) DESCRIPTION

The demo software was developed for the purpose of reviewing the functionality of the sensor, that is, it was made to serve as a tool to confirm the design concept. The software can also be used for testing purposes, or during FAT proximity sensor tests. The software is built in the LabView environment. [6]

For the Proximity sensor vPST-M23 function to be tested, the following equipment (Figure 14) is necessary:

1. Computer with Windows 7 or Windows 19.
2. UART/USB interface
3. CP210x Silicon Labs Windows drivers for UART/USB interface
4. Software vPST-M23 FDT

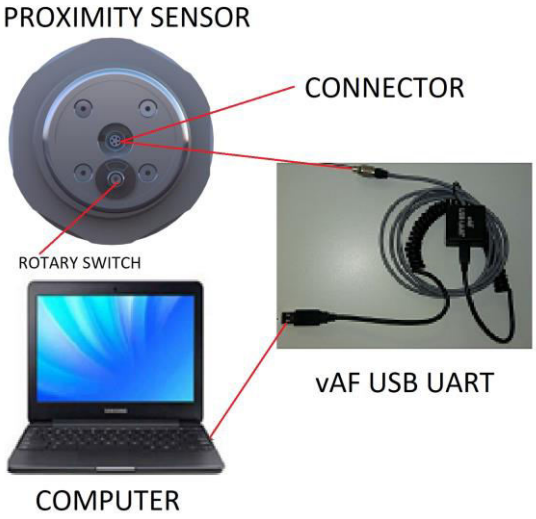

Figure 14. Proximity sensor testing equiment

It is necessary to check which communication port is selected:

C:/My Computer/Control Panel/Device manager/Ports(COM&LPT)

Select COM x which is used for Silicon Labs CP210xUSB to UART Bridge. Start the application software vPST-M23 FDT. On the screen of the computer, the graphical interface will appear according to the Figure 15.

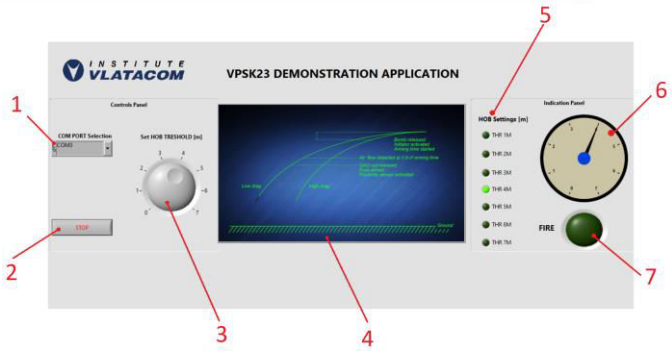

Figure 15. vPST-M23 FDT software user interface

Figure 15 shows the user interface of the software, which includes:

1. The function of selecting the com port of the computer to which the vAF USB-UART is connected
2. Button to stop the functions of the device
3. Switch for software setting of desired HOB
4. Visual identification of the state of the device
5. Identification of the numerical value of the physical position of the rotary switch
6. Visual identification of the set value of the desired HOB
7. Identification of detection of obstacles, ground surfaces, vehicles and other.

When the proximity sensor detects an obstacle at the set HOB value, the software interface changes, which means that the fire signal is activated. The indicator on the user interface under number 7 in Figure 15 changes color, which tells us that the sensor has detected an obstacle and that the signal from the sensor has been sent to the fuze, which is shown in Figure 16.

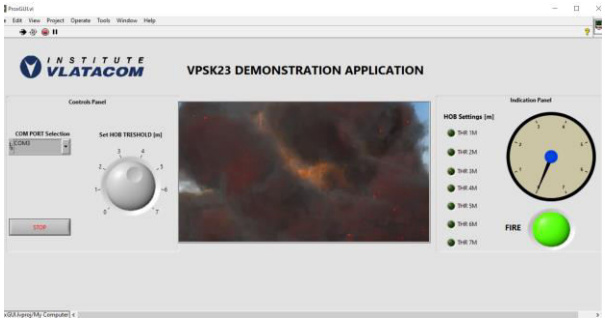

Figure 16. vPST-M23 FDT software user interface in active mode

VI. CONCLUSION

The proximity sensor vPS-M23 completes the function of the fuze vAF-M23, in addition to the impact and delay functions, the proximity function is added to the fuze, which enables the system to be universal, which means that the type of function of the fuze can be chosen depending on the target, and gives the fuze (system) a much greater choice of applications.

The software that was developed confirms the design concept and based on the results of this software and the device itself, conclusions can be drawn that the sensor performs the tasks for which it is intended and that, in combination with the fuze and the initiator, it forms a very significant system that improves the effect of the warhead. In addition to this, software can be used during more detailed factory tests of proximity sensor, that is, it can be used to confirm the results of these tests.

The software can be used to check the sensor before use, in order to confirm the condition of the sensor before it is placed in the warhead.

This software and hardware were developed for the needs of the P166 project of the Vlatacom Institute, in order to confirm the function of the sensor and the sensor design concept.

REFERENCES

[1] Dilley, N. E. "Development of Proximity Fuzes (VT) for Projectiles - VT Fuzes MKS 32 to 60, Inclusive (General Description)." chapter 1 of The World War II Proximity Fuze: A Compilation of Naval Ordnance Reports by the Johns Hopkins University Applied Physics Laboratory. (Silver Spring MD: The Laboratory, 1950): 1-12. [declassified 16 Jun. 1976].

[2] A. Nasser, Fathy M. Ahmed, K. H. Moustafa, Ayman Elshabrawy "Recent Advancements in Proximity Fuzes Technology", International Journal of Engineering Research & Technology (IJERT), Vol. 4 Issue 04, April-2015, ISSN: 2278-0181

[3] "Chapter 14 Fuzing". Fundamentals of Naval Weapons Systems. Weapons and Systems Engineering Deptartment, United States Naval Academy – via Federation of American Scientists.

[4] Young, C. G. "Notes on Fuze Design". Journal of the United States Artillery.

[5] Brad A. Myers, “Graphical user interface programming”

[6] https://www.ni.com/en-rs/shop/labview.html

[7] V. Milićević, N. Zdravković, J. Jović, D. Jagličić. (2022). “Model development to software platform for beehive field placement optimization”, Acta Agriculturae Serbica, ISBN 0354-9542, vol. 27 (53) 2022 UDC 638.1:004.4, DOI: 10.5937/AASer2253039M

[8] D. Mikić, D. Eleonora, N. Radivojević, A. Ašonja, V. Milićević. (2017). "Software modeling of multi-degree-of-freedom motion system using matrices", Springer - Journal of the Brazilian Society of Mechanical Sciences and Engineering (BMSE) – J Braz. Soc. Mech. Sci. Eng. DOI 10.1007/s40430-017-0745-5