WEAPON ORIENTATION MODULE

WOM

Model number WOM.03.04, WOM.03.05

Interface Control Document

Revision 5.5

CHANGE STATUS LOG		
DOCUMENT: Inertial Labs™ WOM Interface Control Document		
REVISION	DATE	REMARKS
1.0 to 3.9		Skipped
4.0	Nov.11, 2011	**For WOM3 firmware since v.4.8.0.3** 1. 3D calibration is realized and its description is added. Start3DClb command is added. 2. Added AcceptClb command for 3D calibration. 3. After receiving the StopClb command the calibration parameters are automatically saved to the WOM nonvolatile memory only at zone-based calibration. At other types of calibration the AcceptCLb command should be sent to the WOM for this purpose. 4. WOM answers on ExitClb command with check sum. 5. Changed order of bytes #2 and #3 in the payload of the WOM answer on GetClbRes command (Table 6.13)
4.1	Jan.24, 2012	**For WOM3 firmware since v.4.8.1.1** 1. 2D2T calibration is realized and its description is added. 2. Commands for WOM3 calibration are combined in new section 6.3. 3. Added Appendix D. Full list of the Inertial Labs™ WOM commands.
For WOM-3 model starting from WOM.03.04, firmware since v.4.9.1.2		
5.0	Jan.24, 2012	1. Changed UART to RS232 interface. 2. Changed male to female connector. 3. Added specifications for WOM.03.04, WOM.03.05 model number. 4. Deleted section 5 division into subsections.
5.1	Jan.31, 2012	**For WOM3 firmware since v.4.9.1.5** 1. 2D calibration is realized and its description is added. 2. Because of added 2D calibration the WOM answers on StopClb and GetClbRes commands are updated (Table 6.14, Table 6.15)
5.2	May 24, 2012	**For WOM3 firmware since v.4.9.1.6** 1. Format updates. 2. Changed maximum angular rate in WOM specifications (Table 3.1). 2. Inserted 4 bytes float for set-point azimuth in the WOM message after each calibration run (Table 6.12).
5.3	May 20, 2013	1. Added recommendations to section 4.2. 2. Updated links on website for WOM connectors. 3. Added note in the Table 6.12 for bytes 16-27 4. Separated description of the StartClbRun command for

		zone-based and 2D-2T calibration 5. StopClb command but not WOMStop is used to stop data accumulation in the run. 6. Specified default values of alignment angles of the WOM mounting on weapon. 7. Augmented Note 3 under Table C.3 for WOM firmware since v.4.9.6.3.
5.4	Sep.24, 2013	**For WOM3 firmware since v.4.9.9.0** 1. Corrected byte numbers in Table 6.2. 2. StopClb command that was used both to stop data accumulation in the run and to finish calibration with multiple runs, is separated on two commands: a) StopClbRun command for stop data accumulation in the run, see section 6.3.3; b) FinishClb command for finish calibration with multiple runs, see section 6.3.4. 3. Table 6.12 describes WOM message for zone-based calibration only. For 2D-2T calibration the new Table 6.15 is inserted. 4. Corrected Tables 6.12, 6.14, 6.16 for changed fields of WOM messages at calibration procedures. 5. Added estimation of accuracy of hard/soft iron calibration, with appropriate change in WOM output data .
5.5	10-Oct-13	WOM specifications updated

TABLE OF CONTENTS

1. INTRODUCTION

Inertial Labs™ WOM-3 (see fig.1.1) is designed for measuring Euler orientation angles (azimuth, pitch and roll) of a weapon in static and dynamic environment. It consists of three MEMS gyros, three MEMS accelerometers, three magnetometers with internal power regulations and embedded microprocessor. Original Inertial Labs™ algorithm is used for above sensors signal processing to achieve high accuracy of attitude and azimuth determination.

Fig.1.1. The Inertial Labs™ WOM-3

Fig.1.2 shows the WOM-3 own coordinate system $Ox_oy_oz_o$. This coordinate system is body-fixed and defined as the calibrated sensors coordinate system. Non-orthogonality between the axes of the body-fixed coordinate system $Ox_oy_oz_o$ is about 0.01°.

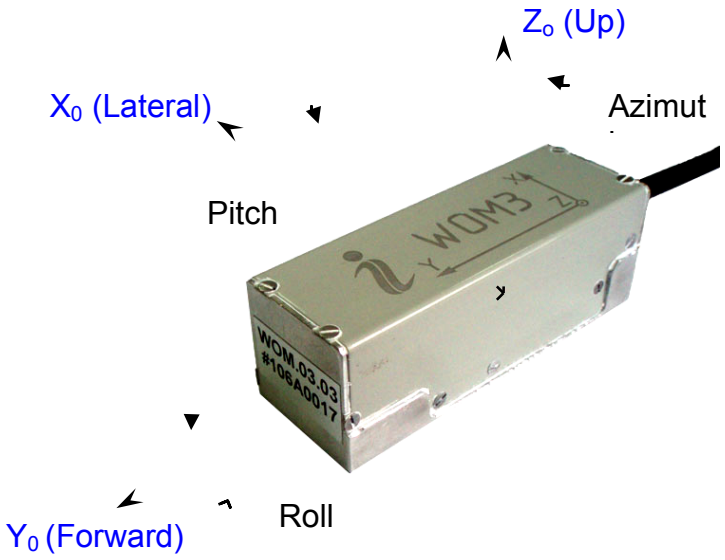

Fig.1.2. Coordinate system of the Inertial Labs™ WOM-3

Measured angles are the standard Euler angles of rotation from the Earth-level frame (East-North-Up) to the body frame, azimuth first, then pitch, and then roll.

2. SCOPE AND APPLICABILITY

This Interface Control Document (ICD) provides details on mechanically mounting, the electrical connections, powering and software interface between the Inertial Labs™ WOM-3 and OneTESS Player Unit or another host computer.
This document is intended for all parties requiring such information, including engineers and researchers responsible for implementing the interface.

3. SPECIFICATIONS

There are 5 models of the Inertial Labs™ WOM-3 which utilize different sensors and a different interface:

- WOM.03.01 – with ±800 deg/s range gyros, UART interface;
- WOM.03.02 – with ±800 deg/s range gyros and magneto-inductive magnetometers, UART interface;
- WOM.03.03 – with ±300 deg/s range gyros, UART interface;
- WOM.03.04 – with ±300 deg/s range gyros, RS232 interface;
- WOM.03.05 – with ±1000 deg/s range gyros, RS232 interface;

Table 3.1. Inertial Labs™ WOM-3 specifications

Parameter	Units	Part number: WOM-G300-A2-TMGA-C1-V3.5
Output signals		Euler angles; Quaternion; Accelerations; Angular rates; Magnetic field, Delta Theta and Delta Velocity
Update rate	Hz	1 … 100 (user settable)
Start-up time	sec	< 1
Full Accuracy Data (Warm-up Time) (1)	sec	30
Heading		
Range	deg	0 to 360
Angular Resolution	deg	0.01
Static Accuracy in whole Temperature Range (2)	deg	0.17
Noise (at 100 Hz output)	deg RMS	0.03
Attitude		
Range: Pitch, Roll	deg	0 to 360
Angular Resolution	deg	0.01
Static Accuracy in whole Temperature Range	deg	0.1
Noise (@100 Hz)	deg RMS	0.02
Angular Rate		
Gyroscopes measurement range (3)	deg/s	±300
In-run Bias Stability at Constant Temperature	deg/s RMS	0.02
Bias stability in whole Temperature Range	deg/s RMS	0.2
Scale Factor Accuracy	%	0.1
Gyroscopes noise	deg/sec√Hz	0.035
Axis misalignment	mrad	0.15
Resolution	deg/sec	0.01
Bandwidth	Hz	50
Linear Acceleration		
Accelerometers measurement range	g	±2
In-run Bias Stability at Constant Temperature	mg RMS	0.05
Bias Stability in whole Temperature Range	mg RMS	1
Bias turn-on, turn-on repeatability	mg RMS	0.1
Scale Factor Accuracy	%	0.1
Accelerometers noise	mg√Hz	0.04
Axis misalignment	mrad	0.15
Resolution	mg	0.1
Bandwidth	Hz	50
Environment		
Operating temperature	deg C	-30 to +50
Storage temperature	deg C	-40 to +85
Non-operating vibration (4)	g, Hz	10-50Hz, 0.15mm/55-500Hz 2.0g
Non-operating shock (5)	g, ms	50g, 11ms, half sine wave
MTBF	hours	55500
Electrical		
Supply voltage	V DC	+5.5 to +6.5
Current draw in readiness mode	mA	87
Current draw in awake mode	mA	67
Current draw in sleep mode 1	mA	20
Current draw in sleep mode 2	mA	15
Interface		
Standard	-	RS-232
Baud Rate	Bps	115200
Data Bits	Bits	8
Physical		
Size	mm	76 × 27 × 26
Weight	gram	70

WOM specifications notes

(1) including time of initial alignment, it may be decreased on request
(2) in homogeneous magnetic environment, for latitude up to ±65 deg
(3) WOM modification with ±1,000 deg/sec gyro measurement range is also available
(4) MIL-STD 810F. Method 514.5. Procedure I
(5) MIL-STD 810F. Method 516.5. Procedure I

4. MECHANICAL INTERFACE

4.1. Where to install the Inertial Labs™ WOM-3 for tests

The Inertial Labs™ WOM-3 has magnetometers with wide dynamic range and its sophisticated calibration algorithms allow it to operate in many environments. For optimal performance however, you should mount the Inertial Labs™ WOM-3 with the following considerations in mind.

- ***Locate the Inertial Labs™ WOM-3 away from local sources of magnetic fields***

The place for testing must not have ferromagnetic (magneto-susceptible) materials and the lab room itself must have the level of intrinsic magnetic and electro-magnetic fields suitable for the magnetic heading system testing:

- inside and near the lab room there must be no powerful source of magnetic, electrical and electro-magnetic fields. The magnetic field intensity must not be different from the Earth magnetic field intensity at the test site more than 0.01%;
- small ferromagnetic objects must be as far as 3 meters from the test table. Large size ferromagnetic objects such as cars and trucks must be as far as 15 m from the table;
- it is necessary to conduct a regular check-up of the magnetic field uniformity inside the lab room.

It is highly recommended to degauss WOM-3 before azimuth test to remove permanent magnetization of some components in the WOM (if you accidentally expose the unit to a large magnetic field). You can use a hand-held degausser (tape eraser) to demagnetize the WOM. Most audio and video degaussing units can be used. Follow the instructions for your demagnetizer.

If azimuth accuracy is not checked and only pitch and roll accuracy are tested then there are no requirements to magnetic fields and ferromagnetic materials near place of the Inertial Labs™ WOM-3 mounting,

- ***The Inertial Labs™ WOM-3 should be mounted in a physically stable location***

Choose a location that is isolated from excessive shock, oscillation, and vibration. A special rotary table must be used for the Inertial Labs™ WOM-3 accuracy testing that mounted on a special testing basement which is free from the laboratory oscillations and vibrations.

Tests on vibrations and shocks are fulfilled separately from the main accuracy tests.

4.2. Where to install the Inertial LabsTM WOM-3 on the weapon

Usually the Inertial Labs™ WOM-3 is mounted on the barrel of the weapon with additional mounting hardware. Requirements to the mounting hardware:

- mounting hardware should have two mutually perpendicular mounting surfaces necessary to mount Inertial Labs™ WOM-3. Misalignment of the mounting surfaces should be no more than 0.1°;
- mounting hardware should provide alignment of mounting surfaces and axis of the barrel with the error of no more than 0.1°;
- mounting hardware should provide rigid fixation of Inertial Labs™ WOM-3 on the barrel;
- mounting hardware should provide the abut for WOM in frontal part to avoid possible displacements of the WOM during recoil of the weapon.

It is necessary to follow the recommendations listed in the section 4.1 whenever it is possible, when installing the Inertial Labs™ WOM-3 on an carrier object.

- ***Inertial Labs™ WOM-3 should be installed on a weapon as far as possible from large ferromagnetic masses of the weapon and powerful sources of magnetic, electrical and electro-magnetic fields***

Inertial Labs™ WOM-3 software allows compensation of hard and soft iron effects of the weapon on the azimuth determination accuracy. For this purpose, field calibration of the WOM-3 magnetometers is provided. This calibration does not require any additional equipment, but it requires turns of the weapon, on which the WOM-3 is mounted.

Note that the above field calibration is correct until the residual magnetic field of the weapon surrounding the WOM-3 is changed. If this field is changed due to displacement of ferromagnetic masses of the weapon or magnetic field sources, the WOM-3 should be re-calibrated.

Field calibration procedure of the Inertial Labs™ WOM-3 can be performed by two means:

- by WOM-3 itself using special commands described in the section 6.3;
- using the Inertial Labs WOM Demo Program.

The WOM Demo Program provides more variants of the field calibration and is more convenient for use, but it requires connection of the WOM-3 to PC. Calibration of the WOM-3 itself is performed without its disconnection from the host system.

More detailed description of the field calibration procedure is given in the section 6.3. Calibration of the Inertial Labs™ WOM-3 on hard and soft iron.

4.3. Mechanically mounting the Inertial Labs™ WOM-3

The Inertial Labs™ WOM-3 housing has two base surfaces A and B (see Fig.4.1) that are designed for Inertial Labs™ WOM-3 mounting during its run and testing.

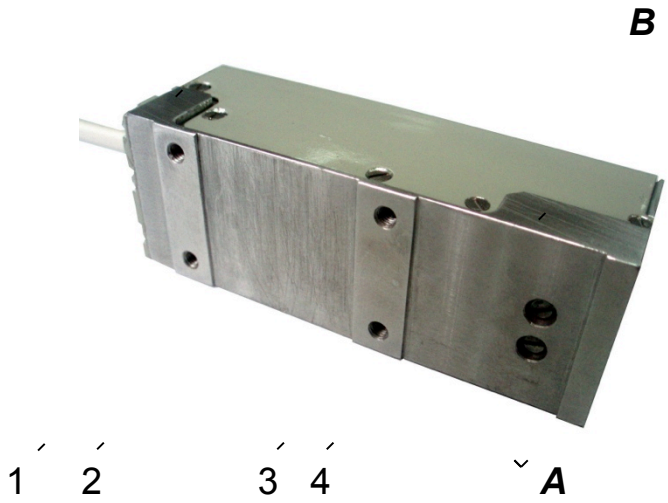

Fig.4.1. The Inertial Labs™ WOM-3 mounting surfaces A, B and mounting holes 1 – 4

Salient bottom base surface A has 4 threaded holes M3x6 mm which are designed for mounting of the WOM-3 (see Fig.4.1, positions 1-4). Lateral base surface B is designed for the WOM-3 alignment during mounting. The Inertial Labs™ WOM-3 is factory calibrated with respect to the base surfaces A and B, thus it must be aligned within the host system (weapon) with respect to these mounting surface, not the device edges.

When mounting Inertial Labs™ WOM-3 on a weapon, please pay attention to orientation of input axes X", "Y", "Z" marked on the cover of the WOM-3. Usually Inertial Labs™ WOM-3 is mounted on the weapon with its axis Y along the shooting direction (weapon barrel). But it is possible to mount the WOM-3 in any other known position (see Appendix B. Variants of the Inertial Labs™ WOM-3 mounting relative to weapon axes).

To obtain accurate attitude and azimuth, please remember that mounting is very important and mounting error can cause attitude and azimuth errors. When the Inertial Labs™ WOM-3 mounting please align it on two base surfaces relative your system axes.

The Inertial Labs™ WOM-3 is mounted using 4 threaded holes M3x6 mm on the bottom of Inertial Labs™ WOM-3 (see Fig.4.1, positions 1-4). Requirements to the mounting surface of the object :

- flatness tolerance is 0,03 mm;
- surface undulation is Ra=1.25.

Fig.4.2 sows the outline drawings of the WOM-3. All dimensions are in millimeters.

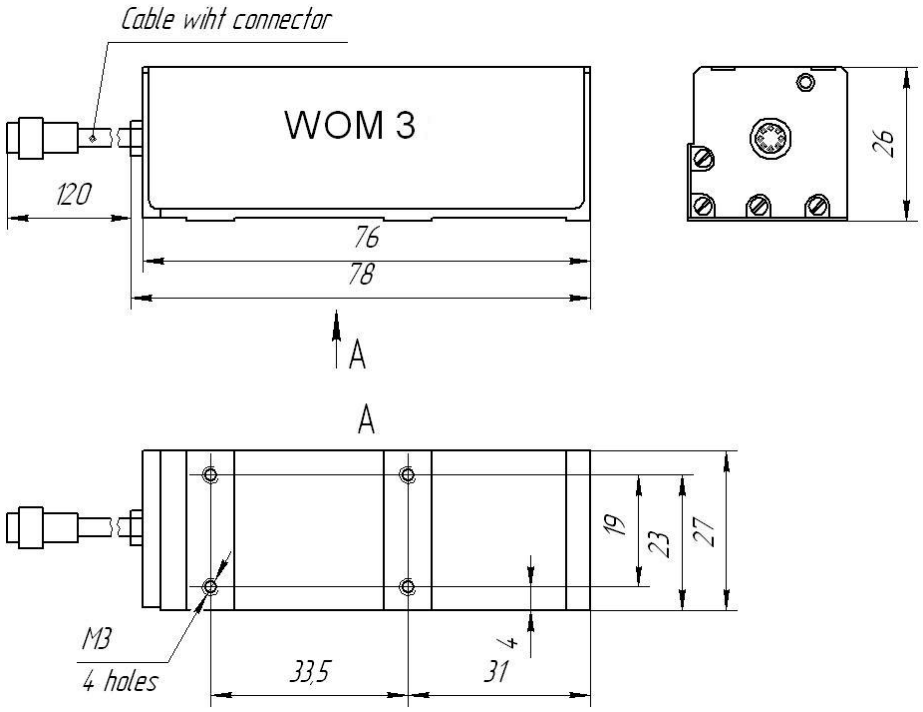

Fig.4.2. The Inertial Labs™ WOM-3 outline drawing

5. ELECTRICAL INTERFACE

The Inertial Labs™ WOM-3.4 and WOM-3.5 have the Binder Series 718 female 6 pin connector (cordset), part # 79-3464-52-06

For electrical connection of the WOM-3.4 and WOM-3.5 to the host system, the Binder Series 718 male 6 pin connector (cordset), part # 79-3465-52-06 or part # 79-3465-55-06 should be used
or Binder Series 768 male 6 pin connectors, part #
09-3463-00-06
09-3423-00-06
09-3423-81-06
09-3423-86-06
09-3463-81-06
09-3463-86-06

Fig.5.1 shows the Inertial Labs™ WOM-3.4 connector pinout. Pin color fits to wire color in mating cordset.

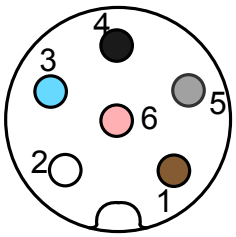

Fig.5.1. The Inertial Labs™ WOM-3.4, WOM-3.5 connector pinout (mating side of the connector)

Table 5.1 Pin diagram of the Inertial Labs™ WOM-3.4 connector

Pin	Signal
1	Do not connect
2	Tx-RS232
3	Rx-RS232
4	GND
5	V_{DD}
6	Do not connect

Note. Do not connect anything to pins #1 and #6 that are connected to WOM-3 PCB for firmware updates.

Table 5.2 Electrical specifications

Parameter	Conditions	Min	Typical	Max	Units
Input Supply		+5.5V	+6V	+6.5V	Volts DC
Current	V_{DD} = +6V	15	85	90	mA
Power	V_{DD} = +6V	90	510	540	mW

At the Inertial Labs™ WOM-3 operations, it is connected to the host system that provides command interface described in the section 6 and the WOM powering.

For tests, the Inertial Labs™ WOM-3 can be connected to PC by wire as Fig.5.2 shows. At this, for the Inertial Labs™ WOM-3 powering the AC/DC adapter can be used which receives the power from the 100…240V 50…60Hz AC power source. This AC/DC adapter is provided by the Inertial Labs and is included in the delivery set.

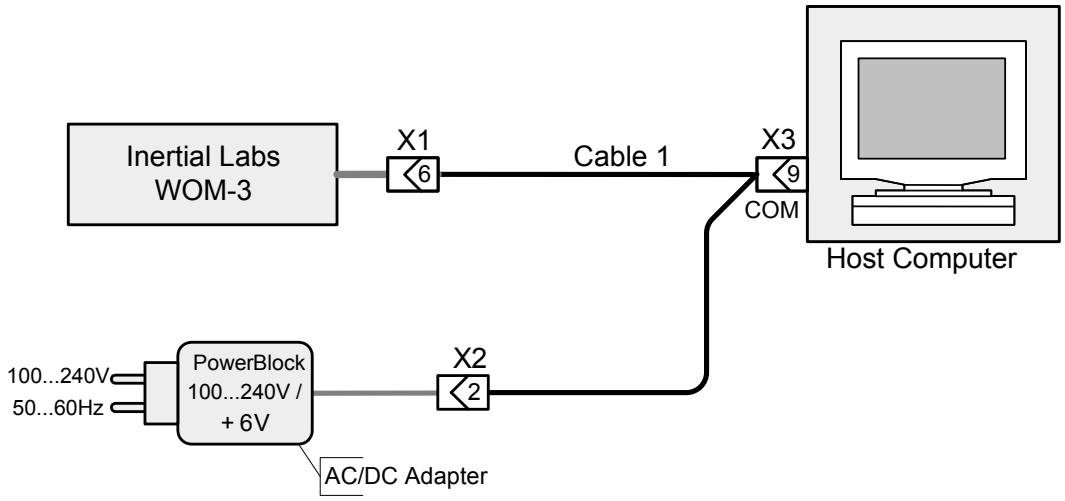

Fig.5.2. The diagram of electric connection of the Inertial Labs™ WOM-3.4 to host computer (PC)

The delivery set for the WOM-3 electrical connection to PC is provided by the Inertial Labs and includes:

- interface cable 1 for the Inertial Labs™ WOM-3 connection to the COM-port of PC or another device, with branch wires for the Inertial Labs™ WOM-3 DC powering;
- COM-to-USB converter for connection of the WOM-3 to PC through the USB port;
- AC/DC adapter.

Also Inertial Labs WOM Demo software is included in the delivery set for quick evaluation of the Inertial Labs™ WOM-3.

Fig.5.3 shows the diagram of the interface cable 1 for the Inertial Labs™ WOM-3 connections to the COM-port of host computer and to the DC power source.

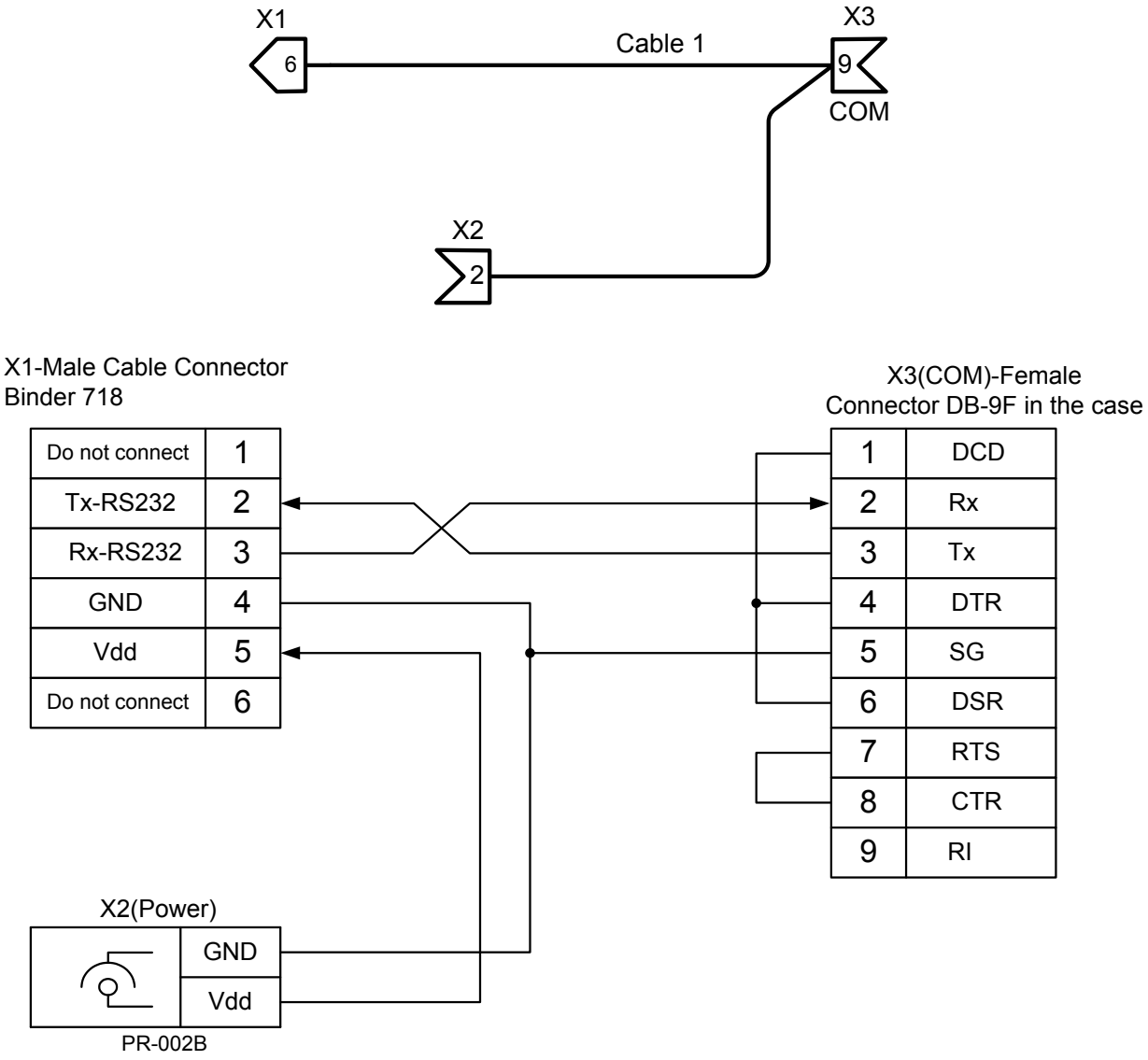

Fig.5.3. The diagram of the interface cable 1 for the Inertial Labs™ WOM-3.4 connections to the COM-port of host computer and to the AC/DC adapter

6. SOFTWARE INTERFACE

After power connection the primary initialization of the Inertial Labs™ WOM-3 microprocessor takes place and the main program starts working. The time of the device pretreatment is not more 1 second. The program works in the waiting mode of the commands.

The commands are transmitted through the serial port according to the protocol RS232.

Table 6.1. COM-port parameters

COM-port parameters	
Baud rate	115200
Data bits	8
Parity	none
Stop bits	1

All commands and messages to / from the Inertial Labs™ WOM-3 have the byte structure shown in the Table 6.2.

Table 6.2. Byte structure for all commands and messages to / from the WOM-3

Byte number	0	1	2	3	4, 5	6 .. (n-1)	n, (n+1)
Parameter	Header 0	Header 1	Message type	Reser-ved	Message length	Payload	Check sum
Length	1 byte	1 byte	1 byte	1 byte	1 **word**	Variable	1 **word**
Note	0xAA	0x55			Equal to n		

Message type is equal to:
0 – for commands;
1 – for transferring data.

All the WOM outputs are data, therefore they have Message type = 1.

The Message length is the number of bytes in the message without header.

The Check sum is the arithmetical sum of bytes 2…(n–1) (all bytes without header). In the check sum the low byte is transmitted first (see Table 6.3).

Table 6.3. Format of the check sum transmitting

byte0	byte1
low byte	high byte

In the Table 6.2 and in all other there is denoted:
word = unsigned 2 byte integer;
sword = signed 2 byte integer.

Important note
The low byte is transmitted by first in all data denoted as word, sword, float.

6.1. Operational modes of the Inertial Labs™ WOM-3

The Inertial Labs™ WOM-3 can operate in the seven modes:

1. **Idle** mode. All sensors and electronics are powered. The WOM microprocessor waits any command from the host computer to start operate in one of the next modes. In the idle mode the WOM's indicator lights red.

2. "**Readiness**" mode. This is a regular WOM mode. At this the WOM operates in the endless loop, providing the continuous calculating of orientation angles with 100 Hz rate using all sensors data and full algorithm of their processing. The WOM outputs the orientation data if WOM detects a blank shot itself or by request from host computer. In the Readiness mode the WOM's indicator lights green.

3. "**Awake**" low-power mode. To decrease the WOM power consumption, the WOM's gyros are switched off, microprocessor operates with low frequency. Orientation angles are calculated using data from accelerometers and magnetometers with low frequency to determine moment when weapon is in shooting position to switch the WOM to the Readiness mode. In the Awake mode the WOM's indicator blinks green.

4. "**Sleep1**" low-power mode with the minimal power consumption of the WOM. All sensors are switched off except one accelerometer. Processor core and almost all periphery are switched off too. Data from one accelerometer are read once per 0.1 second to detect movement of the weapon. Neither outputs from the WOM nor inputs to the WOM are available. Only the WOM itself can exit from Sleep1 mode when movement sensor detects the WOM movement. In the Sleep1 mode the WOM's indicator lamp is off.

5. "**Sleep2**" low-power mode with a little bit greater power consumption than in the Sleep1 mode. All sensors are switched off, processor core and part of periphery are switched off. No outputs are from the WOM, only Its microprocessor waits command from the host computer to exit from Sleep2 mode. In the Sleep2 mode the WOM's indicator lamp is off.

6. "**Continuous**" mode. This mode is used for the WOM evaluation. In this mode the WOM operates in the endless loop, providing the continuous

output of calculated orientation angles and some other data according to chosen output data format (see Appendix C. The WOM-3 operation in the "Continuous" and on the "On Request" evaluation modes). Data rate is set by user from 1 Hz to 100 Hz. In the Continuous mode the WOM's indicator lights green.

7. "**On Request**" mode. This mode is used for the WOM evaluation. It is close to the "Continuous" mode, but the WOM sends only one data block after each Request command issued from host computer.

6.2. Control of the Inertial Labs™ WOM-3

After power connection the WOM-3 is in the idle mode. Red light of the indicator lamp near the connector signifies readiness of the Inertial Labs™ WOM-3 to receive commands from the host computer. When the WOM-3 switches from idle to any operation mode, the light indicator changes its color from red to green or blinking green.

The next commands are used to control the WOM-3:

- WOMStart;
- WOMStop;
- GetOrientation;
- ReadWOMPar;
- LoadWOMPar;
- LowPowerOn;
- LowPowerOff;
- GetVerFirmware;
- GetBIT.

All these commands have the byte structure shown in the Table 6.2. Payload for all commands has length 1 byte and contains code of the command. See Appendix D for exact structure of these commands.

Also there are some additional commands for control the WOM-3 in the "**Continuous**" and "**On Request**" modes that are used for the WOM-3 evaluation (see Appendix C. The WOM-3 operation in the "Continuous" and on the "On Request" evaluation modes).

6.2.1. WOMStart command

The **WOMStart** command is used to start the Inertial Labs™ WOM-3 in the "Readiness" operating mode. Payload in the command byte structure (see Table 6.2) is equal to the code 0x91 of this command.

In order to identify to the system that WOM received the WOMStart command, WOM answers back immediately on this message prior to completion of the initial alignment process. The WOM calculates the check sum of the message (without its header and check sum) and returns it for a checking. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (1 word). This check sum should be equal to the check sum in the message that was sent to the WOM.

After receiving the WOMStart command the WOM-3 starts process of initial alignment that takes usually 10 seconds. This process includes the WOM gyros drift estimation, therefore don't move the WOM-3 during its initial alignment. If this requirement is not met then large errors may be occurred in orientation angles determination.

Note: Default time 10 seconds of the initial alignment can be changed (see section 6.2.4. LoadWOMPar command) but only in agreement with developers of the Inertial Labs™ WOM-3.

After completing of the initial alignment the WOM-3 gives out the block of the initial data (payload is 50 bytes of the data – see the Table 6.4) and goes in the "Readiness" operating mode.

Table 6.4. Structure of the payload of block of initial alignment data

Byte	Parameter	Format	Length	*Note*
0-11	Gyros bias	**float**	**3*4**	3 numbers in ADC codes
12-23	Average acceleration	**float**	**3*4**	3 numbers in ADC codes
24-35	Average magn. field	**float**	**3*4**	3 numbers in ADC codes
36-39	Initial Azimuth	**float**	**4**	degrees
40-43	Initial Roll	**float**	**4**	degrees
44-47	Initial Pitch	**float**	**4**	degrees
48-49	USW (see section 6.4)	**word**	**2**	0 – successful initial alignment; ≠0 – unsuccessful

In the “Readiness” mode the WOM outputs the orientation data if the WOM detects a shot itself or by request from the host computer (wireless module). Format of the WOM output in the “Readiness” mode is described in the Table 6.5

Table 6.5. Payload of the WOM-3 output data in the Readiness mode

Byte number	0 – 1	1 – 2	4 – 5	6 – 7	8 – 11	12 – 13	14 – 15
Parameter	Azimuth	Pitch	Roll	Reser-ved	USW	Vdd	Utermo
Length	2 byte word	2 byte sword	2 byte sword	4 byte	2 byte word	2 byte word	2 byte sword
Note	Orientation angles, deg*100					Supply voltage, VDC*1000	Temperature, °C*10

Notes:
1. USW is unit status word (see section 6.4 for details).
2. Vdd is input voltage of the WOM.
3. Utermo is averaged temperature in 3 accelerometers.

Switching between “Readiness” and low power modes (“Sleep1”, “Sleep2”, “Awake”) depends on parameter Multi_Modes (see section 6.2.4. LoadWOMPar command).

6.2.2. GetOrientation command

The **GetOrientation** command (code 0xC0 in the “Payload” field, see the Table 6.2) is request from the host computer (wireless module) to get the WOM orientation at shot moment. In this case just the host computer designates the shot moment but not the WOM detects it. For this a some kind of trigger mechanism or button is used to simulate the dry shot.

As answer on the GetOrientation command the WOM-3 outputs one block of orientation data with payload according to the Table 6.5.

6.2.3. WOMStop command

At receiving the **WOMStop** command (code 0xFE in the “Payload” field) the WOM stops work in operating mode and goes to the idle mode. At that the light indicator of the WOM changes its color to red.

Important Note: Before using all other commands please send the **WOMStop** command to the WOM to switch device into the idle mode. Be sure that the WOM’s light indicator is red before sending of any other commands.

6.2.4. LoadWOMPar command

The **LoadWOMPar** command (code 0x40 in the "Payload" field) is used to load the block of the WOM-3 parameters (which are available for changing by user) into the WOM nonvolatile memory. After sending the LoadWOMPar command, the block of the WOM-3 parameters must be send to the WOM in the message shown the Table 6.2 with payload shown in the Table 6.6. This message should be sent without pause after sending the LoadWOMPar command.

Table 6.6. Payload of the message following after the LoadWOMPar command (block of parameters for loading to the WOM)

Byte	Parameter	Format	Length	*Note*
0-1	Update rate	**word**	**2**	(1 … 100) Hz, default is 100 Hz
2-3	Initial alignment time	**word**	**2**	seconds, default is 10 sec
4-7	Magnetic declination, Mdec	**float**	**4**	degrees, if Mdec > 360 then WOM calculates it
8-11	Latitude	**float**	**4**	degrees
12-15	Longitude	**float**	**4**	degrees
16-19	Altitude	**float**	**4**	meters
20-23	Date (Year, Month, Day)	**float**	**4**	Year + (Month -1)/12 + Day/365
24-27	Alignment angle A1	**float**	**4**	Angles of the WOM mounting on the weapon, degrees (see Appendix B)
28-31	Alignment angle A2	**float**	**4**	
32-35	Alignment angle A3	**float**	**4**	
36-46	Reserved		**11**	
47	Weapon type, W_type	**byte**	**1**	According to the PAN standard
48	The WOM modes switching, Multi_Modes	**byte**	**1**	See note 4 below this table
49	Method of shot detection, Shot_detect	**byte**	**1**	See note 5 below this table

The WOM-3 calculates the check sum of received parameters and returns it for a checking. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (2 bytes).

Notes:

1. Before using **LoadWOMPar** command it is necessary to use **ReadWOMPar** command (see below) to read parameters from the WOM-3 at first. After that user can change some parameters listed in the Table 6.6, and to send back all block of parameters to the Inertial Labs™ WOM-3.

2. Default time 10 seconds of the initial alignment can be changed but only in agreement with developers of the Inertial Labs™ WOM-3.

3. It is necessary to set current latitude, longitude, altitude, year, month, day only in two cases :

a) if the magnetic declination is unknown so its calculation inside the WOM is required for current place and date;

b) before hard/soft iron calibration of the WOM magnetometers (see section 6.3)

4. Multi_Modes parameter sets the method of the WOM low-power modes switching:

0 – disable automatic switching of the WOM low-power modes;

1 – enable automatic switching the WOM between "Readiness", "Awake" and "Sleep1" modes using own sensors data.

Switching to and awake from "Sleep2" mode is always enable and realized by commands LowPowerOn and LowPowerOff from the host computer (wireless module) – see sections 6.2.6, 6.2.7.

5. Shot_detect parameter specifies the method of shot detecting:

0 – disable the shot detecting;

1 – the WOM auto-detection of blank shot using shock sensor itself (only for WOM with installed shock sensor);

2 – the WOM auto-detection of dry shot using WOM sensors.

6. Default values of Multi_Modes and Shot_detect parameters are depended on W_type parameter (see the Table 6.7).

Table 6.7. Default values of the Multi_Modes and Shot_detect parameters depending on the weapon type

Weapon type, **W_type**	Method of the WOM modes switching, **Multi_Modes**	Method of shot detection, **Shot_detect**
To be specified	To be specified	To be specified

6.2.5. ReadWOMPar command

The **ReadWOMPar** command (code 0x41 in the "Payload" field, see the Table 6.2) is used to read block of the Inertial Labs™ WOM-3 parameters (50 bytes) from the WOM nonvolatile memory.

After receiving ReadWOMPar command, the WOM sends out the message with structure according to Table 6.2 and payload shown in the Table 6.8.

Table 6.8. Payload of the WOM answer on the ReadWOMPar command (block of parameters read from the WOM)

Byte	Parameter	Format	Length	*Note*
0-1	Measurement rate	**word**	**2**	Hz
2-3	Initial alignment time	**word**	**2**	seconds
4-7	Magnetic declination	**float**	**4**	degrees
8-11	Latitude	**float**	**4**	degrees
12-15	Longitude	**float**	**4**	degrees
16-19	Altitude	**float**	**4**	meters
20-23	Date (Year, Month, Day)	**float**	**4**	Year + (Month -1)/12 + Day/365
24-27	Alignment angle A1	**float**	**4**	Angles of the WOM mounting on the weapon, degrees (see Appendix B)
28-31	Alignment angle A2	**float**	**4**	
32-35	Alignment angle A3	**float**	**4**	
36-43	Device ID	**char**	**8**	**only read**
44-46	Reserved		**3**	
47	Weapon type, W_type	**byte**	**1**	According to the PAN standard
48	The WOM modes switching, Multi_Modes	**byte**	**1**	See note 1 below this table
49	Method of shot detection, Shot_detect	**byte**	**1**	See note 2 below this table

Notes:

1. Multi_Modes parameter indicates the current state of the WOM low-power modes switching:

0 – disabled automatic switching of the WOM low-power modes;

1 – enabled automatic switching the WOM between “Readiness”, “Awake” and “Sleep1” modes using own sensors data.

Switching to and awake from “Sleep2” mode is always enable and realized by commands LowPowerOn and LowPowerOff from the host computer (wireless module) – see sections 6.2.6, 6.2.7.

2. Shot_detect parameter specifies method of shot detecting:

0 – shot auto-detection is disabled;

1 – the WOM auto-detection of blank shot using shock sensor itself (only for WOM with installed shock sensor);

2 – the WOM auto-detection of dry shot using WOM sensors.

6.2.6. LowPowerOn command

The **LowPowerOn** command (code 0xB0 in the "Payload" field, see the Table 6.2) switches the WOM-3 to low power "Sleep2" mode. At this command all WOM sensors are switched off, processor core and part of periphery are switched off. No outputs are from the WOM, Its microprocessor only waits command from the host computer to exit from the Sleep2 mode. In the Sleep2 mode the WOM's indicator lamp is off.

6.2.7. LowPowerOff command

The **LowPowerOff** command (code 0xBA in the "Payload" field, see the Table 6.2) awakes the WOM-3 from "Sleep2" mode and switches it to the idle mode with normal power consumption.

6.2.8. GetVerFirmware command

The **GetVerFirmware** command (code 0x1F in the "Payload" field) is used to read firmware version of the WOM-3 (50 bytes) from the WOM nonvolatile memory. As answer the WOM-3 sends out the message with structure according to the Table 6.2 and payload shown in the Table 6.9.

Table 6.9. Payload of the WOM answer on the GetVerFirmware command

Byte	Parameter	Format	Length	*Note*
0-49	Firmware version	**char**	**50**	

6.2.9. GetBIT command

The Inertial Labs™ WOM-3 has continuous built-in monitoring of its health. In the Readiness mode the WOM-3 sends out Unit Status Word (USW) in each data block after a shot detect (see the Table 6.5). The USW includes redundant information about the WOM state that the PAN standard requires for BIT information. On the other hand, the most part of the WOM BIT can be formed only in the wireless module.

Therefore, the wireless module forms the BIT_RESULTS Message based on own data and the USW data received from the WOM.

The USW can be got in any time if the WOM-3 is in Idle or Readiness operation mode (after WOMStart command). For this the **GetBIT** command (code 0x1A in the "Payload" field) is used. In answer the WOM sends out the message with data according to the Table 6.10.

Table 6.10. Payload of the WOM answer on the GetBIT command

Byte number	0 – 1	2 – 3
Parameter	Utermo100	USW
Length	2 byte word	2 byte word

Utermo100 is the WOM temperature in 1/100 °C increments.
The USW is described in the section 6.4.

6.3. Calibration of the Inertial Labs™ WOM-3 on hard and soft iron

The Inertial Labs™ WOM-3 software allows compensation of hard and soft iron effects of the weapon on the azimuth determination accuracy. For this purpose, field calibration of the WOM-3 magnetometers is provided (see Appendix A, The WOM-3 calibration). Inertial Labs utilizes several types of field calibration depending on the weapon type.

The next types of the calibration are realized in the WOM3 firmware:

- zone-based calibration (since firmware version 4.5.3);
- 3D calibration (since firmware version 4.7.1);
- 2D-2T calibration (since firmware version 4.9.1.2).
- 2D calibration (since firmware version 4.9.1.5).

The next commands are used for the WOM-3 calibration:

- StartZoneClb;
- Start3DClb;
- Start2D2TClb;
- Start2DClb;

- StartClbRun;
- StopClbRun;
- FinishClb;
- AcceptClb;
- ClearClb;
- ExitClb;
- GetClbRes.

All these commands have the byte structure shown in the Table 6.2. Payload for all commands has length 1 byte and contains code of the command. See Appendix D for exact structure of these commands.

6.3.1. StartZoneClb command for WOM zone-based calibration

Since WOM-3 firmware version 4.5.3, **zone-based calibration** is realized in the WOM. This calibration is designed for a weapon that operates in limited azimuth range. The calibration procedure involves pointing of the weapon with installed WOM on four corners and intermediate points of the firing zone. This zone is limited by the min/max azimuth and min/max elevation points based on the given weapon. Magnetic azimuth of these points should be known.

To start zone-based calibration the Player Unit sends to the WOM the **StartZoneClb** command (code 0x24 in the “Payload” field) followed by message with block of parameters listed in the Table 6.11. This message have the byte structure shown in the Table 6.2, and should be sent without pause after sending the StartZoneClb command.

The WOM-3 calculates the check sum of received parameters and returns it for a checking. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (1 word).

Table 6.11. Payload of the message following after the StartZoneClb, Start3DClb, Start2DClb and Start2D2TClb commands (the block of parameters loaded to the WOM)

Byte	Parameter	Format	Length	*Note*
0-3	Reference azimuth	**float**	**4**	Magnetic azimuth of the first calibration position, degrees (for StartZoneClb command only)
4-5	Time of data accu-mulation in one run	**word**	**2**	Seconds
6-9	Latitude	**float**	**4**	Degrees
10-13	Longitude	**float**	**4**	Degrees
14-17	Altitude	**float**	**4**	Meters
18-21	Date (Year, Month, Day)	**float**	**4**	Year + (Month -1)/12 + Day/365

Zone-based calibration procedure involves pointing of the weapon with installed WOM in specified positions inside the firing zone. After setting the weapon to the first calibration position with known magnetic azimuth, the StartClbRun command should be sent to the WOM to start first run of the calibration (see section 6.3.2 for details).

The command StartClbRun must be followed by message with block of parameters listed in the Table 6.13. This message have the byte structure shown in the Table 6.2, and should be sent without pause after sending the StartClbRun command.

After receiving the StartClbRun command the WOM calculates the check sum of received parameters and returns it for a checking. This check sum should be equal to the check sum in the StartClbRun command message that was sent to the WOM. Byte structure of this message is shown in the Table 6.1 where payload is the calculated check sum (1 word).

Then the WOM starts accumulation of data during time specified in message sent after the StartZoneClb command (see the Table 6.11). Data accumulation can be stopped before the appointed time by sending StopClbRun command (see section 6.3.3 for details).

Notes:

1. At zone-based calibration the WOM does not perform an initial alignment and starts data accumulation immediately.

2. During calibration run the weapon with installed WOM should be unmovable.

After data accumulation finished, the WOM gives out message with result of the calibration run (see the Table 6.12).

Table 6.12. Payload of the WOM message after each calibration run of zone-based calibration

Byte	Parameter	Format	Length	*Note*
0	Type of calibration	**byte**	**1**	4 for zone-based calibration
1	Calibration point	**byte**	**1**	1, 2, …
2	Remained points	**byte**	**1**	
3	Calibration success	**byte**	**1**	0 – calibration is not successful; >0 – calibration is successful (see Important note below)
4-7	Set-point azimuth, deg	**float**	**4**	
8-11	Average pitch, deg	**float**	**4**	
12-15	Average roll, deg	**float**	**4**	
16-27	Average magneto-meters data, nT	**float**	**3*4**	
28-29	USW	**word**	**2**	See section 6.4

To complete the zone-based calibration procedure, it is necessary to set the weapon with WOM in at least 4-5 points. In each calibration point the StartClbRun command should be send with following message with accurate relative azimuth of the calibration position (relative to the reference).

Important note

Since WOM3 firmware v.4.9.9.0 it provides estimation of the zone-based calibration quality as predicted WOM heading accuracy. To allow this feature it is necessary to have at least 5 points of calibration placed in 4 corners of the zone and in its middle (approximately). The WOM automatically detects these 5 points using parameters “Zone azimuth min”, “Zone pitch min”, “Zone centre threshold” that can be changed using the WOM Demo software

since ver.15.0.28, in the "Device Options" menu. If the WOM detects necessary 5 points in specified zone then it calculates predicted maximum (3 sigma) heading error of the WOM at accepting the calibration, and returns this value in the byte #3 "Calibration success" (see Table 6.12) in degrees*10. For example, byte #3 equal to 5 corresponds to the WOM accuracy ±0.5 deg. If calibration is successful but WOM did not detect those 5 points then the WOM cannot estimate predicted accuracy and returns byte #3 equal to 255.

If the "Calibration success" byte is zero (calibration is not successful yet) in the WOM answer (see the Table 6.12) or it is nonzero (calibration is successful) but predicted WOM heading accuracy is not satisfactory (see above Important note), then weapon should be set in additional calibration position and calibration should be continued. Up to 9 calibration positions are allowed.

If the "Calibration success" byte in the WOM message is nonzero and corresponds to satisfactory WOM heading accuracy (see the Table 6.12 and above Important note) then the calibration can be finished by sending FinishClb command to the WOM (code 0x2C in the "Payload" field – see section 6.3.4 for details). After receiving the FinishClb command the WOM finishes calibration, calculates the calibration parameters and automatically saves them to its nonvolatile memory.
After that the WOM gives out message with the calibration results (see the Table 6.14).
After each calibration run completed there are 3 alternatives of commands that can be send to the WOM:

1. To send the FinishClb command (code 0x2C in the "Payload" field) as it was described above to finish calibration, to calculate calibration parameters and to save them to the WOM nonvolatile memory.
   Notes:
   1. If to send FinishClb command then calibration will be finished with calculation of calibration parameters and their saving to the WOM nonvolatile memory even at not successful calibration (If the "Calibration success" byte is zero in the WOM answer (see the Table 6.12)).
   2. If to send FinishClb command after less than 4 calibration runs, then the calibration will not be performed because of not enough data and previously saved calibration parameters will be not changed in the WOM.
   3. In WOM firmware before v.4.9.9.0 to finish the zone-based calibration the **StopClb** command (code 0x20) was used instead of **FinishClb** (code 0x2C).

2. To set the weapon in new calibration position and to send the StartClbRun command with following message containing accurate relative azimuth of this calibration position. This is possible even if calibration was already denoted as successful after previous calibration run. This ability can be used to increase the calibration accuracy.

3. To send the ExitClb command (see section 6.3.7) In this case the calibration finishes without any calculations in the WOM and without saving any calibration parameters. The WOM stops work in operating mode and goes into the idle mode.

Important note: If place of the WOM mounting on the weapon is changed, or if the weapon is changed, then the WOM should be re-calibrated on the hard and soft iron of this weapon.

6.3.2. StartClbRun command

If calibration procedure includes more than one run (zone-based and 2D-2T calibration) then the **StartClbRun** command (code 0x2B in the "Payload" field) is used to start each run.
At zone-based calibration the command StartClbRun must be followed by message with block of parameters listed in the Table 6.13. This message have the byte structure shown in the Table 6.2, and should be sent without pause after sending the StartClbRun command.

Table 6.13. Payload of the message following after the StartClbRun command (block of parameters loaded to the WOM)

Byte	Parameter	Format	Length	*Note*
0-3	Relative azimuth	**float**	**4**	Azimuth of the calibration position relative to the reference
4-5	Measurement units	**word**	**2**	0 = degrees; 1 = mils

Note:
Relative azimuth in degrees is positive in case of clockwise rotation from reference to calibration position and negative in case of counter-clockwise rotation. Relative azimuth in mils is positive in case of counter-clockwise rotation from reference to calibration point and negative in case of clockwise rotation (according to sight unit scale).

At 2D-2T calibration the command StartClbRun must be followed by message with block of parameters listed in the Table 6.13, but values of those 6 bytes don't influence, so these 6 bytes may be any, for example zeros. Only requirement is that this message should have the byte structure shown in the Table 6.2, and should be sent without pause after sending the StartClbRun command.

After receiving the StartClbRun command the WOM calculates the check sum of received parameters and returns it for a checking. This check sum should be equal to the check sum in the StartClbRun command message that was sent to the WOM. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (1 word).

6.3.3. StopClbRun command

After receiving the **StopClbRun** command (code 0x20 in the "Payload" field) the WOM early stops data accumulation in the calibration run before set accumulation time is reached.

Then the calibration procedure continues in the same way as after set accumulation time was reached.

6.3.4. FinishClb command for WOM zone-based and 2D-2T calibration

After receiving the **FinishClb** command (code 0x2C in the "Payload" field) the WOM finishes the calibration procedure with multiple runs (zone-based, 2D-2T) and calculates the calibration parameters. After that the WOM gives out message with the calibration results (see the Table 6.14).

Important note: In WOM firmware before v.4.9.9.0 to finish the zone-based or 2D-2T calibration the **StopClb** command (code 0x20) was used instead of **FinishClb** (code 0x2C).

Table 6.14. Payload of the WOM message after calibration completed

Byte	Parameter	Format	Length	*Note*
0	Type of calibration	**byte**	**1**	1 for 2D calibration; 2 for 2D-2T calibration; 3 for 3D calibration; 4 for zone-based calibration.
1	Number of used calibration runs (points)	**byte**	**1**	
2	Percent of used data points	**byte**	**1**	for 2D and 3D calibrations only
3	Calibration success	**byte**	**1**	0 – calibration is not successful >0 – calibration is successful (see Note below)
4-39	Matrix for soft iron correction	**float**	**9*4**	Matrix Tm_c (3×3) by rows
39-51	Matrix for hard iron correction	**float**	**3*4**	Matrix Hm_0 (3×1)

Note: since WOM3 firmware v.4.9.9.0 it provides estimation of the calibration quality as predicted WOM heading accuracy. So nonzero value of byte #3 "Calibration success" is predicted maximum (3 sigma) heading error of the WOM after calibration, in degrees*10. For example, byte #3 equal to 5 corresponds to the WOM accuracy ±0.5 deg. If calibration is successful but WOM cannot estimate predicted accuracy it returns byte #3 equal to 255.

After that In the zone-based calibration the calculated calibration parameters are automatically saved to the WOM nonvolatile memory even at not successful calibration (If the "Calibration success" byte is zero in the WOM answer).

In the 2D-2T calibration the WOM waits one of the next commands:

- the AcceptClb command (see section 6.3.6) to accept and save the calibration parameters;
- or the ExitClb command (see section 6.3.7) to exit from calibration procedure without accepting and saving its results.

6.3.5. Start2D2TClb command for WOM 2D-2T calibration

Since WOM3 firmware version 4.9.1 the **2D-2T calibration** is realized in the WOM. This calibration is designed for weapons that operate in full azimuth range but with limited range of pitch and roll angles (like mortars). This calibration procedure involves a few full 360° rotations of the weapon in azimuth with different pitch angles.

To start the 2D-2T calibration the Player Unit sends to the WOM the **Start2D2TClb** command (code 0x22 in the "Payload" field) followed by message with block of parameters listed in the Table 6.11. This message have the byte structure shown in the Table 6.2, and should be sent without pause after sending the Start2D2TClb command. Note that first 4 bytes in the payload (Reference azimuth) do not influence on the 2D2T calibration as it is noted in the Table 6.11.

The WOM calculates the check sum of received parameters and returns it for a checking. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (1 word).

The 2D-2T calibration procedure involves a few runs with full 360° rotations of the weapon with installed WOM in azimuth with different pitch angles.

Set the weapon to the first pitch angle (usually the minimum pitch angle is set first). Then send the StartClbRun command (see section 6.3.2 for details) to start the first run of the calibration.

For unification with the StartClbRun command for the zone-based calibration (see section 6.3.1) this command must be followed by message with block of parameters listed in the Table 6.13. But for the 2D-2T calibration the value of those 6 bytes does not influenced, so these 6 bytes may be any, for example zeros. Only requirement is that this message should have the byte structure shown in the Table 6.2, and should be sent without pause after sending the StartClbRun command.
After receiving the StartClbRun command with above message, the WOM calculates the check sum of received block of parameters and returns it for a checking. This check sum should be equal to the check sum in the StartClbRun command message that was sent to the WOM. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (1 word).

Then the WOM starts process of initial alignment. This process includes the WOM gyros drift estimation, therefore don't move the WOM during its initial alignment. Default time of the initial alignment is 10 seconds and can be changed (see section 6.2.4. LoadWOMPar command) but only in agreement with developers of the Inertial Labs™ WOM3.

After completing of the initial alignment the WOM gives out the block of the initial data (payload is 50 bytes of the data – see the Table 6.4) and starts data accumulation during time specified in message sent after the Start2Clb command (see the Table 6.11). Rotate weapon in azimuth with approximately constant pitch and roll. This rotation must include one or more full 360 deg turns. Please, correct the time required for such rotation in the «Time of data accumulation» field of the message (Table 6.11) to provide necessary rotation.

After set accumulation time is reached or StopClbRun command is sent to the WOM (see section 6.3.3 for details) the WOM gives out message with result of the calibration run (see the Table 6.15).

Table 6.15. Payload of the WOM message after each calibration run of 2D-2T calibration

Byte	Parameter	Format	Length	*Note*
0	Type of calibration	**byte**	**1**	2 for 2D-2T calibration
1	Calibration run	**byte**	**1**	1, 2, …
2	Percent of used data points	**byte**	**1**	
3	Calibration success	**byte**	**1**	0 – calibration is not successful; >0 – calibration is successful (see Note below)
4-7	Reserved	**float**	**4**	
8-11	Average pitch, deg	**float**	**4**	
12-15	Average roll, deg	**float**	**4**	
16-27	Reserved	**float**	**3*4**	
28-29	USW	**word**	**2**	See section 6.4

If the "Calibration success" byte is zero (calibration run is not successful) in the WOM answer (see the Table 6.15) then this run will be excluded from calculations in the 2D-2T calibration procedure. To complete this procedure, it is necessary to perform at least two successful runs with essentially different pitch angles.

Note: since WOM3 firmware v.4.9.9.0 it provides estimation of the calibration quality as predicted WOM heading accuracy. So nonzero value of byte #3 "Calibration success" is predicted maximum (3 sigma) heading error of the WOM after calibration, in degrees*10. For example, byte #3 equal to 5 corresponds to the WOM accuracy ±0.5 deg. If calibration is successful but WOM cannot estimate predicted accuracy it returns byte #3 equal to 255.

After each calibration run completed the WOM sends message with payload shown in the Table 6.15, and it waits one of the next three commands from the host computer (Player Unit):

1. StartClbRun command followed by message with 6 bytes block of any data but with the byte structure shown in the Table 6.2 – to start new calibration run. Before send this command the weapon should be turned to the next pitch angle. After sending this command the above described procedure of the calibration run with weapon rotation in azimuth should be performed.

2. FinishClb command (see section 6.3.4 for details) to finish the calibration procedure and to calculate calibration parameters. After that the WOM gives out message with the calibration results (see the Table 6.14) and waits one of the two commands:
   a. the AcceptClb command (see section 6.3.6) to accept and save the calibration parameters (usually if the "Calibration success" byte in the WOM message is nonzero and corresponds to satisfactory WOM heading accuracy (see the Table 6.14 and Note below it));
   b. or the ExitClb command (see section 6.3.7) to exit from calibration procedure without accepting and saving its results (usually if the "Calibration success" byte in the WOM message is equal to 0 or corresponds to not satisfactory WOM heading accuracy (see the Table 6.14 and Note below it)).

   The WOM answers on these commands with checksum and goes to idle mode.

Note: In WOM firmware before v.4.9.9.0 to finish the 2D-2T calibration the **StopClb** command (code 0x20) was used instead of **FinishClb** (code 0x2C).

3. ExitClb command (see section 6.3.7) In this case the calibration finishes without any calculations in the WOM and without saving any calibration parameters. The WOM answers on this command with checksum and goes into the idle mode.

Notes:
1. Rotation of the weapon with the WOM in azimuth must include one or more full 360° turns. Please, correct the time required for saving data in the «**Accumulation time»** window to attain necessary rotations.
2. During calibration run pitch and roll angles should be approximately constant.
3. If place of the WOM mounting on the weapon is changed, or if the weapon is changed, then the WOM should be re-calibrated on the hard and soft iron of this weapon.

6.3.6. AcceptClb command

The **AcceptClb** command (code 0x2E in the "Payload" field) is applied to accept the calibration parameters and to save them to the WOM nonvolatile memory. This command can be used in the end of the 3D, 2D or 2D-2T calibration.

The WOM answers on this command. The WOM calculates the check sum of the message (without its header and check sum) and returns it for a checking. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (1 word).

6.3.7. ExitClb command

The **ExitClb** command (code 0xFE in the "Payload" field) is used to exit from the calibration without any calculations in the WOM and without saving any calibration parameters. The WOM stops work in operating mode and goes into the idle mode.

The WOM answers on this command. The WOM calculates the check sum of the message (without its header and check sum) and returns it for a checking. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (1 word).

6.3.8. Start3DCIb command for WOM 3D calibration

Since WOM3 firmware version 4.7.1 the **3D calibration** is realized in the WOM. This calibration is designed for weapons that can operate in full azimuth, pitch and roll ranges. At this calibration the weapon should be rotated in all these ranges.

To start the 3D calibration the Player Unit sends to the WOM the **Start3DCIb** command (code 0x23 in the "Payload" field) followed by message with block of parameters listed in the Table 6.11. This message have the byte structure shown in the Table 6.2, and should be sent without pause after sending the Start3DCIb command. Note that first 4 bytes in the payload (Reference azimuth) do not influence on the 3D calibration as it is noted in the Table 6.11.

The WOM calculates the check sum of received parameters and returns it for a checking. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (1 word).

Then the WOM starts process of initial alignment. This process includes the WOM gyros drift estimation, therefore don't move the WOM during its initial alignment. Default time of the initial alignment is 10 seconds and can be changed (see section 6.2.4. LoadWOMPar command) but only in agreement with developers of the Inertial Labs™ WOM.

After completing of the initial alignment the WOM gives out the block of the initial data (payload is 50 bytes of the data – see the Table 6.4) and starts data accumulation during time specified in message sent after the Start3DCIb command (see the Table 6.11).

During the WOM data accumulation the weapon should be rotated in full azimuth, pitch and roll ranges. For example the weapon is rotated in the horizon plane (the Z-axis is up) with periodical stops about each 90 degrees for tilting in pitch and roll. After full 360° rotation the weapon with the WOM is turned over (the Z-axis is down) and the procedure described above should be repeated. During this calibration the range of pitch and roll angles changing must be as much as possible.

Note: since WOM3 firmware v.4.9.9.0 it provides estimation of 3D calibration quality in terms of possible WOM heading accuracy. To allow this possibility it is necessary to include additional rotation of the WOM with the carrier object in the horizon plane on about 360 degrees or more with pitch and roll near the level. Acceptable pitch and roll change can be set using WOM Demo Software since ver.15.0.28 by the "Pitch/Roll threshold" parameter in the "Device Options".

After set accumulation time is reached or StopClbRun command is sent to the WOM (see section 6.3.3 for details) the WOM finishes data accumulation and calculates the calibration parameters.

After calculation of the calibration parameters that takes <0.5 seconds, the WOM gives out message with the calibration results (see the Table 6.14) and it waits one of the next commands:

- the AcceptClb command (see section 6.3.6) to accept and save the calibration parameters (usually if the "Calibration success" byte in the WOM message is nonzero and corresponds to satisfactory WOM heading accuracy (see the Table 6.14 and Note below it));
- or the ExitClb command (see section 6.3.7) to exit from calibration procedure without accepting and saving its results (usually if the "Calibration success" byte in the WOM message is equal to 0 or corresponds to not satisfactory WOM heading accuracy (see the Table 6.14 and Note below it)).

The WOM answers on these commands with checksum and goes to idle mode.

6.3.9. Start2DClb command for WOM 2D calibration

Since WOM3 firmware version 4.9.1.5 the **2D calibration** is realized in the WOM. This calibration is designed for weapons that operate in full azimuth range but with small pitch and roll angles (not more than a few degrees). This calibration procedure involves full 360° rotation of the weapon in azimuth. During this rotation pitch and roll angles must be as close to zero as possible.

To start the 2D calibration the Player Unit sends to the WOM the **Start2DClb** command (code 0x21 in the "Payload" field) followed by message with block of parameters listed in the Table 6.11. This message have the byte structure shown in the Table 6.2, and should be sent without pause after sending the

Start2DClb command. Note that first 4 bytes in the payload (Reference azimuth) do not influence on the 2D calibration as it is noted in the Table 6.11.

The WOM calculates the check sum of received parameters and returns it for a checking. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (1 word).
Then the WOM starts process of initial alignment. This process includes the WOM gyros drift estimation, therefore don't move the WOM3 during its initial alignment. Default time of the initial alignment is 10 seconds and can be changed (see section 6.2.4. LoadWOMPar command) but only in agreement with developers of the Inertial Labs™ WOM.

After completing of the initial alignment the WOM gives out the block of the initial data (payload is 50 bytes of the data – see the Table 6.4) and starts data accumulation during time specified in message sent after the Start2DClb command (see the Table 6.11). Rotate weapon in azimuth with pitch and roll angles close to zero as possible. This rotation must include one or more full 360 deg turns. Please, correct the time required for such rotation in the «Time of data accumulation» field of the message (Table 6.11) to provide necessary rotation.
After set accumulation time is reached or StopClbRun command is sent to the WOM (see section 6.3.3 for details) the WOM finishes data accumulation and calculates the calibration parameters.
After calculation of the calibration parameters that takes <0.5 seconds, the WOM gives out message with the calibration results (see the Table 6.14) and it waits one of the next commands:

- the AcceptClb command (see section 6.3.6) to accept and save the calibration parameters (usually if the "Calibration success" byte in the WOM message is nonzero and corresponds to satisfactory WOM heading accuracy (see the Table 6.14 and Note below it));
- or the ExitClb command (see section 6.3.7) to exit from calibration procedure without accepting and saving its results (usually if the "Calibration success" byte in the WOM message is equal to 0 or corresponds to not satisfactory WOM heading accuracy (see the Table 6.14 and Note below it)).

The WOM answers on these commands with checksum and goes to idle mode.

6.3.10. ClearClb command

The **ClearClb** command (code 0x2F in the "Payload" field) is used to clear parameters of the hard and soft iron calibration from the WOM nonvolatile memory.

The WOM answers on this command. The WOM calculates the check sum of the message (without its header and check sum) and returns it for a checking. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (1 word).

You should clear parameters of the soft and hard iron calibration if you uninstall the WOM from weapon to avoid incorrect azimuth determination with standalone WOM.

6.3.11. GetClbRes command

The **GetClbRes** command (code 0x2A in the "Payload" field) can be send from the Player Unit to check the last calibration results of the WOM. As answer on this command the WOM sends out the message with the data block near the same as after completing calibration, see the Table 6.16.

Table 6.16. Payload of the WOM answer on request GetClbRes about calibration results

Byte	Parameter	Format	Length	*Note*
0	Type of calibration performed	**byte**	**1**	0 – WOM is not calibrated; 1 – 2D calibration; 2 – 2D-2T calibration; 3 – 3D calibration; 4 – zone-based calibration; >0x80 – WOM is calibrated by loading calibration parameters from other software (e.g. Demo software).

1	Number of used calibration points (runs)	**byte**	**1**	
2	Reserved	**byte**	**1**	
3	Calibration success	**byte**	**1**	0 – calibration is not successful >0 – calibration is successful (see Note below)
4-39	Matrix for soft iron correction	**float**	**9*4**	Matrix Tm_c (3×3) by rows
39-51	Matrix for hard iron correction	**float**	**3*4**	Matrix Hm_0 (3×1)

Note: since WOM3 firmware v.4.9.9.0 it provides estimation of the calibration quality as predicted WOM heading accuracy. So nonzero value of byte #3 "Calibration success" is predicted maximum (3 sigma) heading error of the WOM after calibration, in degrees*10. For example, byte #3 equal to 5 corresponds to the WOM accuracy ±0.5 deg. If calibration is successful but WOM cannot estimate predicted accuracy it returns byte #3 equal to 255.

6.4. The Unit Status Word definition

The Unit Status Word (USW) provides the WOM-3 state information. The low byte (bits 0-7) of USW indicates failure of the WOM-3. If this byte is 0, the WOM-3 operates correctly, if it is not 0, see the Table 6.17 for type of failure. The high byte (bits 8-15) contains a warning or is informative for the user. Status of each bit of the USW warning byte is specified in the Table 6.17 and Table 6.18.

Table 6.17. The Unit Status Word description

	Bit	Parameter	Description
Low (failure) byte	0	Initial Alignment	0 – Successful initial alignment 1 – Unsuccessful initial alignment due to WOM moving or large changing of outer magnetic field
	1	WOM-3 Parameters	0 – Parameters are correct 1 – Parameters are incorrect
	2	Gyroscope Unit	0 – No failure 1 – Failure is detected
	3	Accelerometer Unit	0 – No failure 1 – Failure is detected
	4	Magnetometer Unit	0 – No failure 1 – Failure is detected
	5	Electronics	0 – No failure 1 – Failure is detected
	6	Software	0 – No failure 1 – Failure is detected
	7	WOM-3 mode	See the Table 6.18
High (warning) byte	8	Incorrect Power Supply	0 – Supply voltage is not less than minimum level 1 – Low supply voltage is detected
	9		0 – Supply voltage is not higher than maximum level 1 – High supply voltage is detected
	10	Angular Rate Exceeding Detect	0 – X-angular rate is within the range 1 – X-angular rate is outrange
	11		0 – Y-angular rate is within the range 1 – Y-angular rate is outrange
	12		0 – Z-angular rate is within the range 1 – Z-angular rate is outrange
	13	Large Magnetic Field Detect	0 – Total magnetic field is within the normal range 1 – Total magnetic field limit is exceeded
	14	Environmental Temperature	0 – Temperature is within the operating range 1 – Temperature is out of the operating range
	15	WOM-3 mode	See the Table 6.18

The WOM-3 indicates its current mode of operation in the bits 7 and 15 as the Table 6.18 shows.

Table 6.18. Indication of the WOM current operational modes

USW bits		WOM mode
Bit #7	Bit #15	
0	0	Readiness
0	1	Awake
1	1	Sleep (this is in the last data block sent by the WOM before it went to Sleep mode)

APPENDIX A

The Inertial Labs™ WOM-3 calibration

The Inertial Labs WOM-3 software allows to take into account influence of the weapon soft and hard iron on the azimuth determination. For this purpose, field calibration of the WOM-3 magnetometers on hard and soft iron is provided. This calibration does not require any additional equipment, but it requires setting of the weapon, where the WOM is mounted, in specified positions.

There are several types of the calibration realized onboard the WOM3:

- zone-based calibration – since firmware version 4.6.6;
- 3D calibration – since firmware version 4.8.0.3;
- 2D-2T calibration – since firmware version 4.8.1.1;
- 2D calibration – since firmware version 4.9.1.5.

Other types of hard/soft iron calibration can be fulfilled with Inertial Labs WOM Demo software.

Zone-based calibration is designed for a weapon that operates in limited azimuth range. The calibration procedure involves pointing of the weapon with installed WOM on four corners and intermediate points of the firing zone. This zone is limited by the min/max azimuth and min/max elevation points based on the given weapon. Magnetic azimuth of these points should be known.

3D calibration is designed for weapons that can operate in full azimuth, pitch and roll ranges. For this calibration the weapon is rotated in the horizon plane (the Z-axis is up) with periodical stops about each 90 degrees for tilting in pitch and roll. After full 360° rotation the weapon with the WOM is turned over (the Z-axis is down) and the procedure described above should be repeated. During this calibration the range of pitch and roll angles changing must be as much as possible.

2D-2T calibration is designed for weapons that operate in full azimuth range but with limited range of pitch and roll angles (like mortars). This calibration procedure involves a few runs with full 360° rotations of the weapon with installed WOM in azimuth with different pitch angles. During each rotation, pitch and roll angles should be as constant as possible.

2D calibration is designed for weapons that operate in full azimuth range but with small pitch and roll angles (not more than a few degrees). This calibration procedure involves full 360° rotation of the weapon with installed WOM in the horizon plane. During this rotation pitch and roll angles must be as close to zero as possible.

If place of the WOM mounting on the weapon is changed, or if the weapon is changed, then the WOM should be re-calibrated on the hard and soft iron of the weapon.

APPENDIX B

Variants of the Inertial Labs™ WOM-3 mounting relative to weapon axes

The Inertial Labs WOM-3 can be mounted on the weapon in any known position (up to upside-down, upright etc.) relative to the weapon axes. Such mounting doesn't change right determination of the weapon orientation if angles of the WOM-3 mounting are correctly stored in the WOM-3 nonvolatile memory.

To store angles of mounting in the WOM-3 please send LoadWOMPar command to the WOM (see structure of the message following after the LoadWOMPar command in the Table 6.6), or use the Inertial Labs™ WOM Demo Program (item «Device option …» from the «Options» menu).

Angles of the WOM position (alignment angles) are set in next order (like azimuth, pitch and roll setting):

- first alignment angle sets position of the WOM-3 longitudinal axis Y relative to longitudinal axes of the weapon measured in the horizontal plane of the weapon. Clockwise rotation is positive;

- second alignment angle is equal to angle of inclination of the WOM-3 longitudinal axis Y relative to the horizontal plane of the weapon. Positive direction is up;
- third alignment angle is equal to inclination angle of the WOM-3 lateral axis X measured around WOM-3's longitudinal axis. Positive rotation is X axis moving down.

All angles are set in degrees.

Some examples of the Inertial Labs WOM-3 mounting relative the weapon are shown on Fig.B.1.

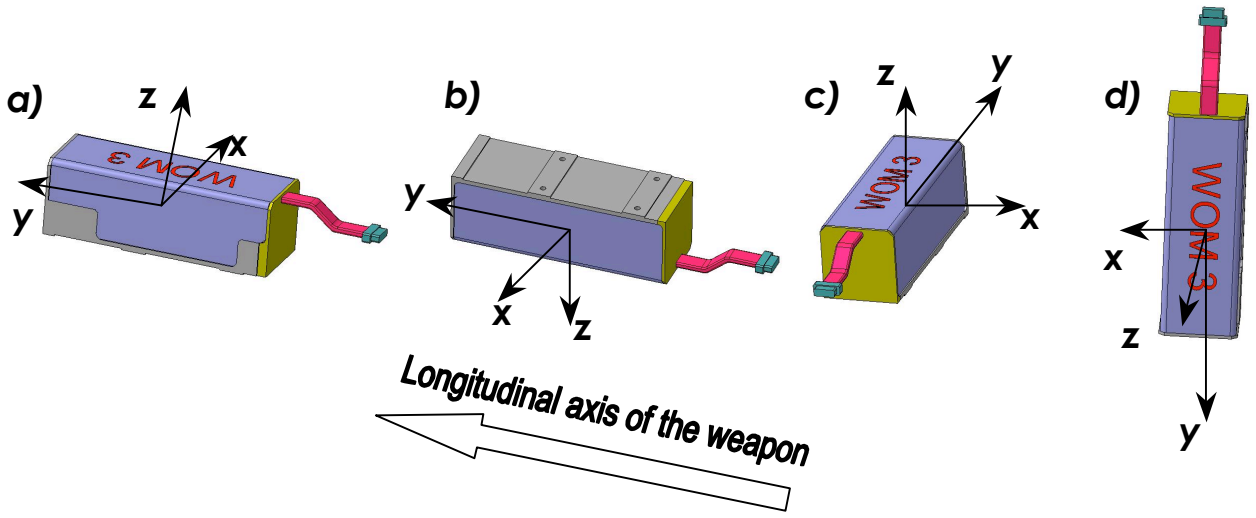

Fig.B.1. Examples of the Inertial Labs™ WOM-3 mounting on the weapon
a – alignment angles are 0, 0, 0 (degrees);
b – alignment angles are 0, 0, 180 (degrees);
c – alignment angles are 90, 0, 0 (degrees);
d – alignment angles are 0, -90, -90 (degrees);

To check correctness of the alignment angles please run the WOM-3 using the Inertial Labs WOM Demo program.

Default values of the WOM alignment angles are all zero. For the WOM installed in the OptoWOM system, default values of these alignment angles are (180, 0, 0) degrees.

APPENDIX C

The WOM-3 operation in the "Continuous" and on the "On Request" evaluation modes

The "Continuous" and "On Request" modes are used for the WOM evaluation. The next output data formats are available both in "Continuous" and "On Request" modes:

- Full Output Data;
- Quaternion of Orientation;
- Orientation + Sensor Outputs.

Usually, "Full Output Data" format is used by the WOM-3 developers for full control of calculations in the WOM microprocessor. Also this format can be used by user at any troubles to get full data from the WOM for next sending them to developers.
"Quaternion of Orientation" format gives quaternion presentation of weapon orientation in addition to 3 orientation angles.
"Orientation + Sensor Outputs" format provides the WOM output in the form of 3 orientation angles (azimuth, pitch and roll) and calibrated outputs of 9 sensors (gyros, accelerometers, magnetometers) that give information about current angular rates, linear acceleration of the WOM-3 and components of outer magnetic field. Sensors data are averaged for cycle of data output.

The next commands are used for control the WOM-3:
- WOMcont1, WOMcont2, WOMcont3 – for the "Continuous" mode;
- WOMreq1, WOMreq2, WOMreq3 – for the "On Request" mode.

All these commands have the byte structure shown in the Table 6.2. Payload for all commands has length 1 byte and contains code of the command.

In order to identify to the system that WOM received one of these commands, the WOM answers back immediately on that message prior to completion of the initial alignment process. The WOM calculates the check sum of the message (without its header and check sum) and returns it for a checking. Byte structure of this message is shown in the Table 6.2 where

payload is the calculated check sum (1 word). This check sum should be equal to the check sum in the message that was sent to the WOM.

- The commands WOMcont1, WOMcont2, WOMcont3 are used to start the Inertial Labs™ WOM-3 in the "Continuous" operating mode with one of four variants of output data:

- **WOMcont1** command, code 0x80 – Full Output Data format,
- **WOMcont2** command, code 0x82 – Quaternion Of Orientation format,
- **WOMcont3** command, code 0x83 – Orientation+Sensor Outputs format.

After receiving of any from these commands the WOM-3 starts process of initial alignment that takes usually 30 seconds. This process includes the WOM gyros drift estimation, therefore don't move the WOM during its initial alignment. If this requirement is not met then large errors may be occurred in orientation angles determination.

Note: Default time 30 seconds of the initial alignment can be changed (see section 6.2.4. LoadWOMPar command) but only in agreement with developers of the Inertial Labs™ WOM-3.

After completing of the initial alignment the WOM gives out message with block of the initial data (payload contains 50 bytes of the data – see the Table 6.4) and goes to the "Continuous" operating mode.

In the "Continuous" operating mode set by any of above commands, the program in the WOM microprocessor operates in the endless loop, providing the process of data reading from ADC and orientation angles calculating. Data blocks are transmitted according to chosen variant of output data in messages described in the Table 6.2.

In all variants the message payload has 34 bytes of data which structure depends on chosen variant of output data. See Table C.1, C.2, C.3 for details where is denoted:
word = unsigned 2 byte integer;
sword = signed 2 byte integer.

The update rate of data blocks is set by the user in range (1...100) Hz. Default update rate is 100 Hz.

Table C.1. The WOM message payload at Full Output Data format
(at WOMcont1 or WOMreq1 command)

Byte number	0 – 1	2 – 3	4 – 5	6 – 23	24 – 25	26	27	28 – 29	30 – 31	32 – 33
Parameter	Azimuth	Pitch	Roll	Ugyro, Uacc, Umag	Shock	Shot	Reser-ved	USW	Vdd	Utermo
Length	2 byte word	2 byte sword	2 byte sword	9×2 byte sword	2 byte sword	1 byte	1 byte	2 byte word	2 byte word	2 byte sword
Note	Orientation angles, deg*100			Raw sen-sors data (gyros, accelero-meters, magne-tometers)	Exter-nal shock sensor is requi-red	Detec-ted shot			Combi-ned voltage VDC* 1000	Tempe rature in each sensor

Notes:

1. Value of the «Shot» field:
0 – no shot;
1 – blank shot;
2 – dry shot detected by WOM inner sensors;
3 – shot simulated by command from host computer

2. The following data are recorded in the field «Vdd» sequentially:
- the WOM-3 input voltage;
- stabilized voltage supplied to the WOM-3 sensors;

3. In the «Utermo» field ADC codes are recorded sequentially from 7 temperature sensors inside gyros, accelerometers and magnetometers.

4. The low byte is transmitted by first.

Table C.2. The WOM message payload at Quaternion of Orientation format
(at WOMcont2 or WOMreq2 command)

Byte number	0 – 1	2 – 3	4 – 5	6 –13	14 – 15	16	17 – 27	28 – 29	30 – 31	32 – 33
Parameter	Azimuth	Pitch	Roll	Lk0, Lk1, Lk2, Lk3	Shock	Shot	Reser-ved	USW	Vdd	Utermo
Length	2 byte word	2 byte sword	2 byte sword	4×2 byte sword	2 byte sword	1 byte	11 bytes	2 byte word	2 byte word	2 byte sword
Note	Orientation angles, deg*100			Quaternion of orientation *10000	External shock sensor is required	Detec-ted shot			Supply voltage, VDC* 1000	Tempe rature, °C*10

Notes:

1. Value of the «Shot» field:
0 – no shot;
1 – blank shot;
2 – dry shot detected by WOM inner sensors;
3 – shot simulated by command from host computer

2. USW is unit status word (see section 6.4 for details).

3. Vdd is input voltage of the WOM-3.

4. Utermo is averaged temperature in 3 accelerometers.

5. The low byte is transmitted by first.

Table C.3. The WOM message payload at Orientation + Sensor Outputs format
(at WOMcont3 or WOMreq3 command)

Byte number	0 – 1	2 – 3	4 – 5	6 – 11	12 – 17	18 – 23	24– 25	26	27	28 – 29	30 – 31	32 – 33
Parameter	Azimuth	Pitch	Roll	GyroX, GyroY, GyroZ	AccX, AccY, AccZ	MagX, MagY, MagZ	Shock	Shot	Reserved	USW	Vdd	Utermo
Length	2 byte word	2 byte sword	2 byte sword	3× 2 byte sword	3× 2 byte sword	3× 2 byte sword	2 byte sword	1 byte	1 byte	2 byte word	2 byte word	2 byte sword
Note	Orientation angles, deg*100			Angular rates, deg/s *KG	Acceleration sg *10000	Magnetic fields, nT/10	External shock sensor is required	Detected shot			Supply voltage, VDC* 1000	Temperature, °C*10

Notes:

1. Value of KG scale factor:
KG=100 for WOM3.4;
KG=50 for WOM3.4 s/n 11BA0001 – 11BA0007;
KG=20 for WOM3.5.

2. Value of the «Shot» field:
0 – no shot;
1 – blank shot;
2 – dry shot detected by WOM inner sensors;
3 – shot simulated by command from host computer

3. Originally angular rates, linear accelerations and magnetic fields are in the WOM axes (X is lateral axis, Y is longitudinal axis, Z is vertical axis). Starting from WOM firmware v.4.9.6.3 axes X, Y, Z are changed to the weapon axes if non-zero alignment angles are set for WOM mounting (see Appendix B. Variants of the Inertial Labs™ WOM-3 mounting relative to weapon axes).

4. USW is unit status word (see section 6.4 for details).

5. Vdd is input voltage of the WOM.

6. Utermo is averaged temperature in 3 accelerometers.

7. The low byte is transmitted by first.

- The commands WOMreq1, WOMreq2, WOMreq3 are used to start the Inertial Labs™ WOM-3 in the "On Request" operating mode with one of above four variants of output data:

- **WOMreq1** command, code 0x84 – Full Output Data format,
- **WOMreq2** command, code 0x86 – Quaternion Of Orientation format,
- **WOMreq3** command, code 0x87 – Orientation + Sensor Outputs format.

After receiving of any from these commands the WOM-3 starts process of initial alignment. After that the WOM gives out message with block of the initial data (payload contains 50 bytes of the data – see the Table 6.4) and goes to the "On Request" operating mode.

In the "On Request" operating mode the WOM-3 sends only one data block after each request command GetDataReq (see below) issued from host computer.

- The **GetDataReq** command (code 0xCA) is used to get one data block from the WOM in the "On Request" operating mode. Command GetDataReq is valid if one of the WOMreq1 … WOMreq3 commands was sent before.

As answer on the GetDataReq command the WOM-3 outputs one block of orientation data with payload according to the Table C.1, C.2 or C.3 (depending on chosen variant of output data).

- At the **WOMStop** command (code 0xFE, see section 6.2.3) the program stops work in operating mode and goes into the idle mode. At that the light indicator changes its color to red.

APPENDIX D

Full list of the Inertial Labs™ WOM commands

All the WOM commands have the byte structure shown in the Table 6.2. Payload for all commands has length 1 byte and contains code of the command. Below Table D.1 lists all commands with their exact structure in hexadecimal numbers.

Table D.1. List of the WOM commands with exact structure

Command name	Code	Exact structure (hex)
Commands for Inertial Labs™ WOM-3 control		
WOMStart	0x91	AA 55 00 00 07 00 91 98 00
WOMStop	0xFE	AA 55 00 00 07 00 FE 05 01
GetOrientation	0xC0	AA 55 00 00 07 00 C0 C7 00
LoadWOMPar	0x40	AA 55 00 00 07 00 40 47 00
ReadWOMPar	0x41	AA 55 00 00 07 00 41 48 00
LowPowerOn	0xB0	AA 55 00 00 07 00 B0 B7 00
LowPowerOff	0xBA	AA 55 00 00 07 00 BA C1 00
GetVerFirmware	0x1F	AA 55 00 00 07 00 1F 26 00
GetBIT	0x1A	AA 55 00 00 07 00 1A 21 00
WOMcont1	0x80	AA 55 00 00 07 00 80 87 00
WOMcont2	0x82	AA 55 00 00 07 00 82 89 00
WOMcont3	0x83	AA 55 00 00 07 00 83 8A 00
WOMreq1	0x84	AA 55 00 00 07 00 84 8B 00
WOMreq2	0x86	AA 55 00 00 07 00 86 8D 00
WOMreq3	0x87	AA 55 00 00 07 00 87 8E 00
GetDataReq	0xCA	AA 55 00 00 07 00 CA D1 00
Commands for Inertial Labs™ WOM-3 calibration		
Start2DClb	0x21	AA 55 00 00 07 00 21 28 00
Start2D2TClb	0x22	AA 55 00 00 07 00 22 29 00
Start3DClb	0x23	AA 55 00 00 07 00 23 2A 00
StartZoneClb	0x24	AA 55 00 00 07 00 24 2B 00
StartClbRun	0x2B	AA 55 00 00 07 00 2B 32 00
StopClbRun	0x20	AA 55 00 00 07 00 20 27 00
FinishClb	0x2C	AA 55 00 00 07 00 2C 33 00
AcceptClb	0x2E	AA 55 00 00 07 00 2E 35 00
ExitClb	0xFE	AA 55 00 00 07 00 FE 05 01
ClearClb	0x2F	AA 55 00 00 07 00 2F 36 00
GetClbRes	0x2A	AA 55 00 00 07 00 2A 31 00