

Boomerang II

Operator's Manual

OM BM000

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BOOMERANG II SYSTEM

OPERATOR'S MANUAL

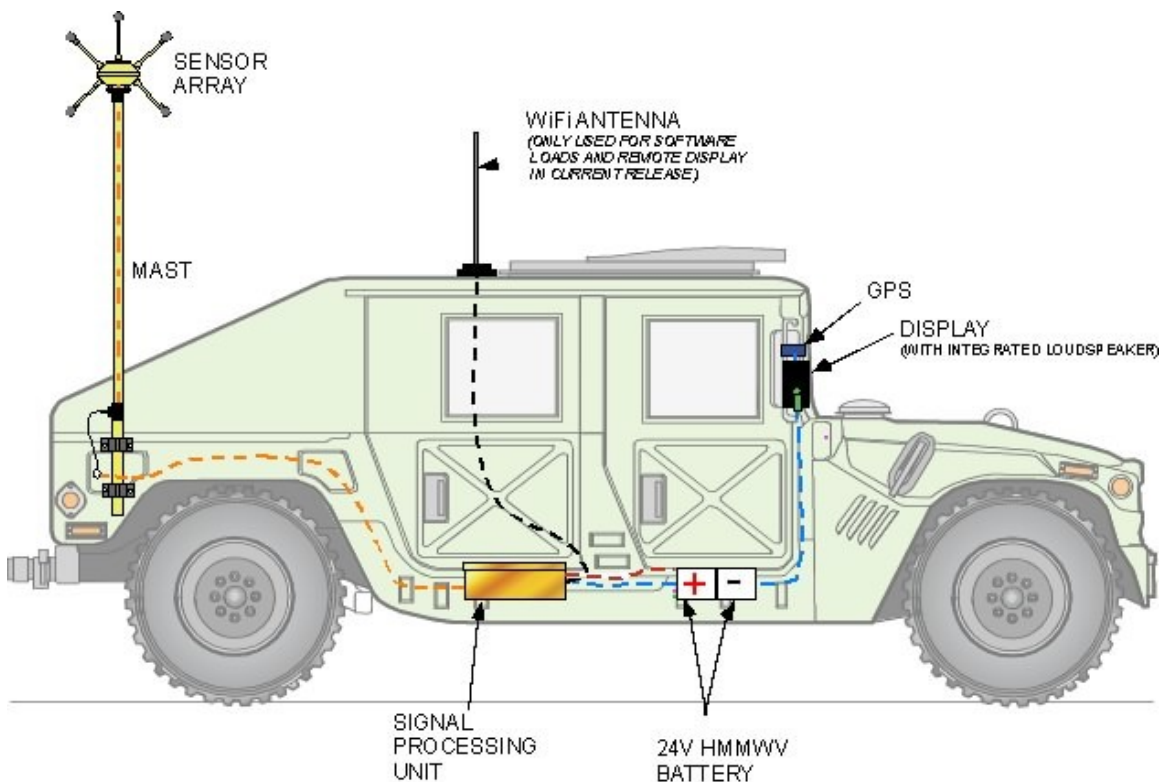


Figure 1: Boomerang II system installation on HMMWV showing the general locations of major system components.

1. Introduction

The BOOMERANG II SYSTEM is an integrated hardware and software system to detect incoming small-arms fire and to indicate the shooter's position by showing the azimuth angle of the shooter relative to the forward direction of the vehicle. System is installed in a HMMWV and operates both when the vehicle is stationary and moving. The system detects the sound of incoming rounds, performs acoustical analysis, and indicates the direction to the shooter both visually and aurally.

2. System Overview

Detection Requirements

- Detect relative shooter direction to ± 15 degrees ('hours of a clock') within 1 second of arrival of bullet shockwave.
- Principal weapon detected is AK-47.
- Urban operations, low buildings, shooter range 50 - 300 meters.
- Missed shot detections fewer than 1 out of 1000 instances.
- Shooter direction errors of greater than ± 15 degrees fewer than 1 out of 500 detections.
- Shot miss distance (CPA): 1 - 30 meters.

Indication

- Voice announcement (e.g. "Shot 3 O'Clock")
- Shooter azimuth indicated by lighted LED on "rose" display of shooter's relative location clockwise from vehicle's front, looking down. (1 O'Clock to 12 O'Clock).
- Shooter azimuth indicated on LCD in degrees clockwise from vehicle's front, looking down.
- Shooter range and elevation provided in feet or meters on LCD display.
- Vehicle's GPS position provided out to 8 positions.

System Description

- Visually distinctive external sensor array..
- Array diameter about .5 meter with full azimuth view.
- Operates using vehicle power only.
- Operator controls consist of on/off switch, Mode, Next/Prev, +/-, Dim, Mute (See Section 2.2.8)
- Operates with vehicle stationary or moving.
- External apparatus withstands impacts of sand, pebbles, rain, and light foliage.
- Operates at temperatures from 0 - 50 Deg. Celsius.
- Field installable.
- Field replaceable microphone array, display, GPS, and Signal Processing Unit.

2.1 System Components

The system consists of a mast-mounted microphone array, an electronic processor, a visual display, and a GPS receiver as depicted in Figure 1 and described in Table 1 below. All components are fixed securely to the vehicle.

Table 1 – System Components

Assembly	Description	Location	Weight
Microphone Mast	Fabricated from 2-inch aluminum pipe (painted sand color). 6.5 ft. overall length, extending 9.5 ft. above the ground. Mast detaches easily from its mounting for low clearance passage.	Left or right rear quarter panel of vehicle.	37 lbs.
Microphone Array	Seven spines approximately 8.5 inches long each attached to an aluminum hub. Each spine fitted with flexibly mounted weatherproof and dustproof microphones having foam windscreens. Maximum height of topmost microphone is approximately 10 ft.	Attached to Hub on Top of Mast at Rear of Vehicle	4 lbs.
Electronics Cabinet	Zinc plated steel box with toggle clamps and mounting flanges; 12" x 10" x 5"	On floor under right-rear seat.	10 lbs.
Visual Display	Display with integrated loudspeaker, headphone jack, Ethernet jack, GPS jack, and remote power ON/OFF switch.	Mounted on dashboard	2 lbs.
GPS receiver	Deluo Electronics GPS	Mounted on dashboard	< 1 lb.

2.2 Hardware Description

2.2.1 Microphone Array

Seven microphones mounted to the end of seven spines are attached to the hub atop the mast as depicted in Figure 2. The microphone assemblies attach to the Hub mechanically and electrically by plugs on the microphone assemblies and receptacles on the Hub.



Figure 2 – Microphone Array, Hub, and Mast Assembly

Each connector has four wires that are terminated in a 4 pin Molex plug that are in turn plugged into corresponding sockets on the analog circuit board in the hub as depicted in Figure 3. The microphone locations are numbered as shown in Figure 4 and engraved into the Hub. However the microphone assemblies are interchangeable. A second circuit board (not shown) is

located below the hub disc plate. This board is called the Digital Hub Board and converts the analog signal to digital and creates an Ethernet link to the Signal Processing Unit to transmit sound data.

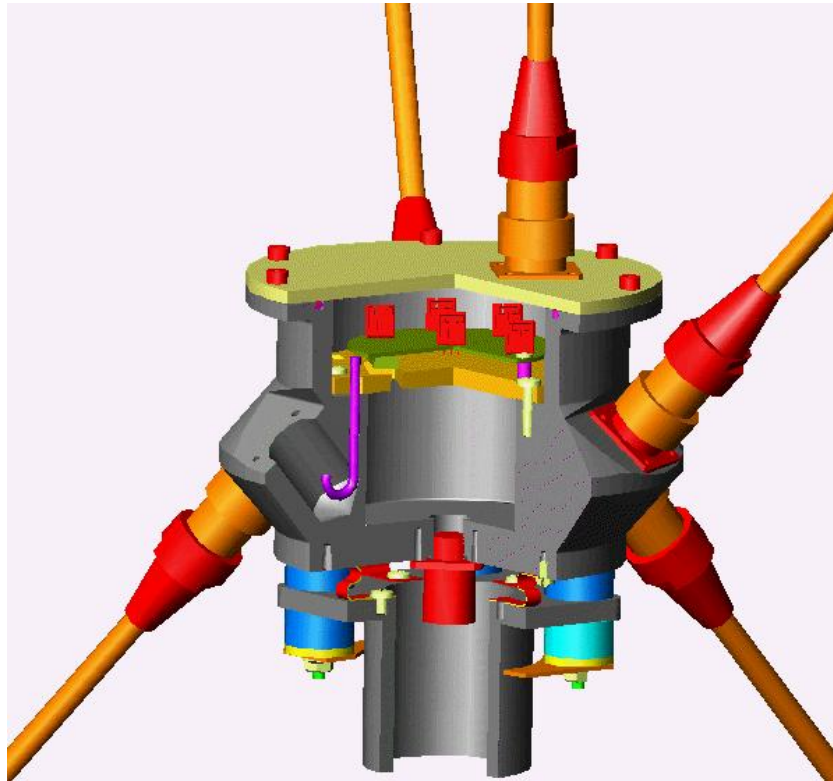


Figure 3: Details of Microphone to Hub Mechanical and Electrical Connectors

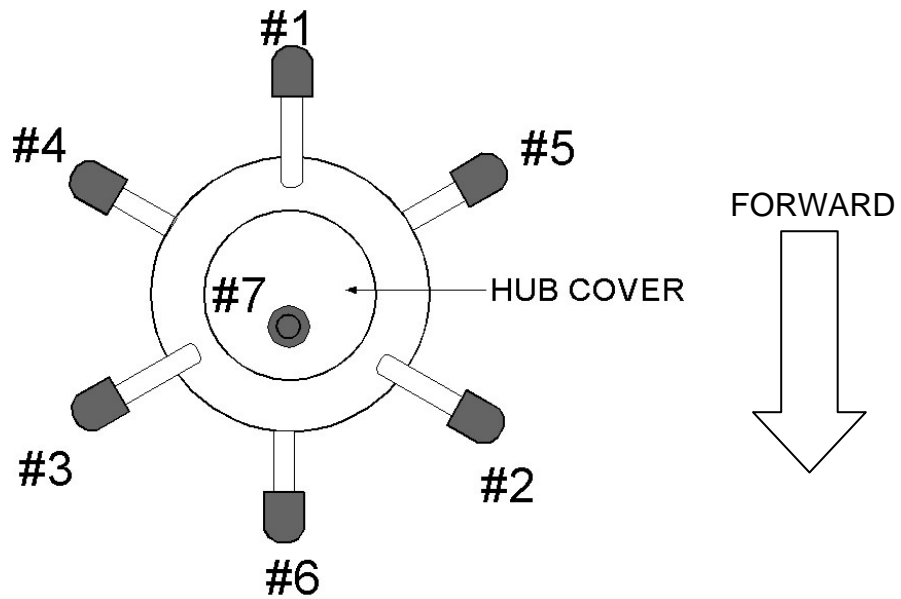


Figure 4: Microphone orientation and attachment locations to the HUB.

Table 3 – Microphone Connector To Hub Board Location Designations

Microphone Number	Hub Connector Location
1	J1
2	J2
3	J3
4	J4
5	J5
6	J6
7	J7

2.2.2 Signal Processing Unit

The signal processing unit is a Nema 4 enclosure bolted to the floor of the HMMWV within the base of the right rear seat. Figure 5 shows the bulkhead connectors used to interface with the Mast and Display.

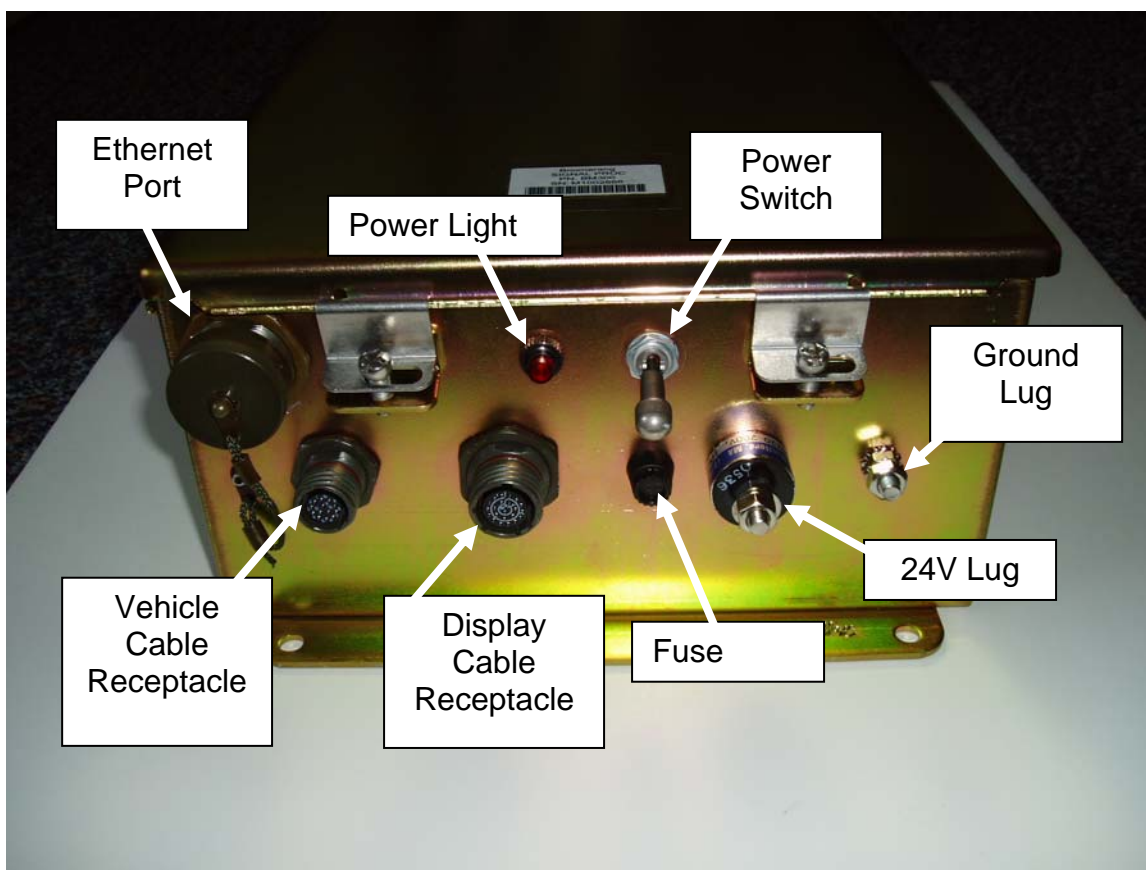


Figure 5: Signal Processing Unit Bulkhead Connectors

Note: The Ethernet jack is not wired to the processor. Use jack on Display Unit.

2.2.3 Visual Display

The visual display front panel includes 12 LEDs, an alphanumeric LCD display, 8 control buttons, and internal loudspeaker, an Ethernet port, a GPS receptacle, a headphone jack, and an ON/OFF switch as shown in Figure 6.



Figure 6: Boomerang Display

2.2.4 Cable Assemblies

There are four main cable assemblies:

- BM200 Mast Cable
- BM201 Vehicle Cable
- BM202 Display Cable
- BM216 Main Power Cable

The Mast Cable is part of the mast assembly and runs for the Hub to the HMMWV Body. The Vehicle cable is part of the installation kit and runs from the HMMWV body to the Signal Processing Unit. The Display Cable is part of the installation kit and runs from the Signal Processing Unit to the Display mounted on the dash. The Main Power Cable is part of the installation kit and

runs from the Signal Processing Unit to the HMMWV battery compartment. Details are shown in the installation manual.

3. Operator Interface

The primary operator interface with Boomerang II is with the display unit, shown in Figure 7.

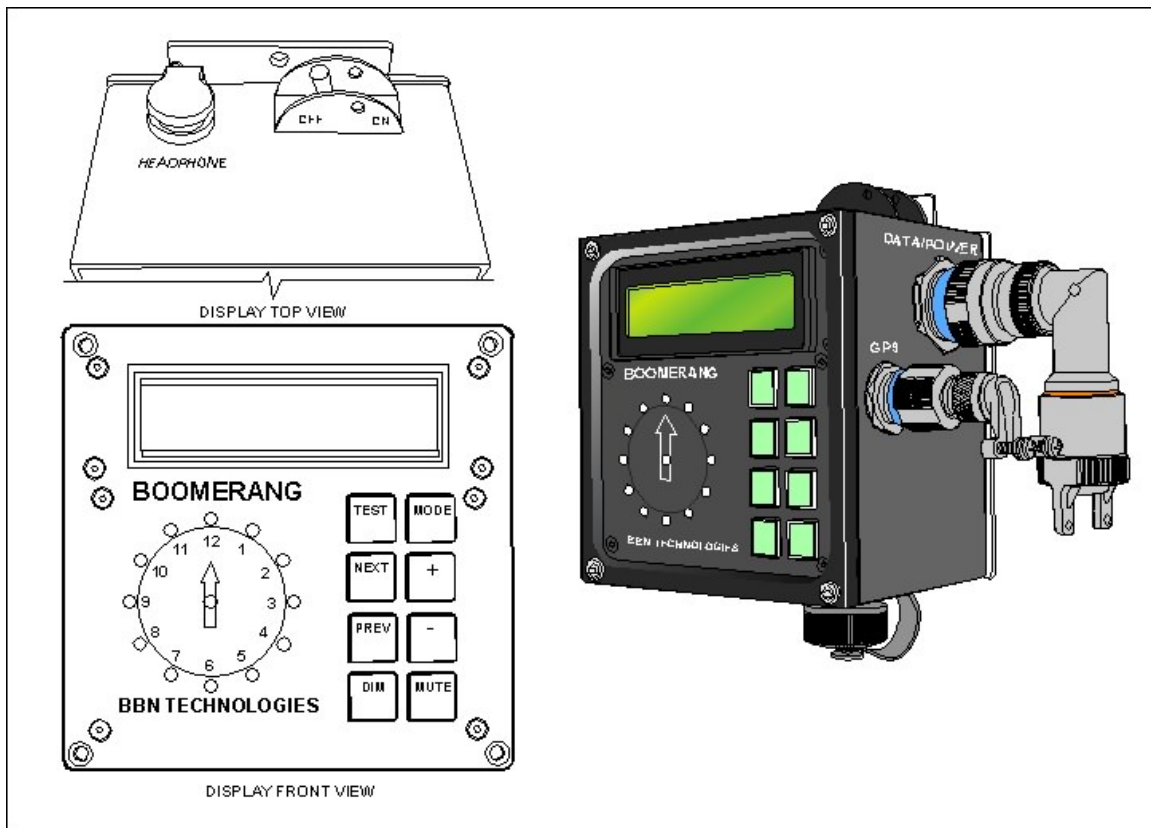


Figure 7 – Display Unit

3.1 Power Switch

This switch powers up the Boomerang system when moved to the ON position. It works by pulling an E-box signal low, which energizes a solid state relay, which powers up the system. The switch is a locking type: the toggle must be deliberately pulled away from the box in order to change its position from on to off (or visa versa).

3.2 Alphanumeric Display

This is a 2 row x 20 character, serial interface, backlit, yellow-green LCD, with RS232 interface. It is used to display GPS/grid coordinate and Boomerang status data.

3.3 GPS Jack

This jack provides a pass-through via which the external GPS module is attached to the corresponding RS232 port within the Signal Processing Unit. This allows a bad/damaged GPS to be swapped out without having to swap out the entire forward wiring harness.

3.4 LED rosette

This is a 12 LED rosette, done in green. The center LED is always lit. The peripheral LEDs are lit either singly (13 possible combinations, including none lit) or in pairs (66 additional combinations), for a grand total of 79. The LED pair combinations can be implemented by toggling rapidly between single LED selections (multiplexing). This approach, which was successfully implemented for the previous display module version, requires only 4 of the Alphanumeric Display output bits to achieve the 13 possible single LED combinations. The illumination level of the LEDs is controlled using the remaining 2 GPS/Status display output bits: off/dim low/dim high/on, and synchronized with that of the GPS/Status Display.

3.5 Speaker

The speaker provides audio output for Boomerang. It uses the left channel output from the SBC audio interface & stereo amplifier located within the E-box. The speaker output level is independent of the gunner headphone level, and is digitally controlled by the left channel of the E-box audio subsystem's integrated stereo mixer.

3.6 Gunner Headphone Jack

This jack provides audio output for a gunner's headphones. Its level is independent of the cabin speaker level, and is digitally controlled by the right channel of the E-box audio subsystem's integrated stereo mixer. It is amplified by the right channel of the stereo amplifier that is used to drive the onboard speaker.

3.7 Ethernet Jack

This jack provides an easily accessible interface point for attaching a maintenance computer (typically a laptop) to Boomerang. It includes a dust cover/plug that is inserted when no other computer is attached.

3.8 Control Buttons

This group of control buttons is a subset of the 5x5 matrix keypad input provided by the Alphanumeric Display serial LCD. Buttons are illuminated with a source controlled by the display dimmer. Every button press is acknowledged by a beep from the audio output speaker.

3.8.1 Test

The test button puts the display in test mode. It is used to verify that all Boomerang's microphones and microphone electronics are functioning properly. In this mode, Boomerang listens for a test sound source (whistle) and indicates on which individual microphone(s) any are detected. When operating properly, every microphone should be able to detect the test sound source. The numbers of the microphones are displayed on the top line of the Alphanumeric Display and a corresponding "+" or "-" is displayed on the bottom line. When Mode 6 is first selected, 7 "-"s are displayed, one for each microphone:

MICROPHONE	1	2	3	4	5	6	7
HEALTH	-	-	-	-	-	-	-

Test data are then generated by a whistle or other sufficiently-characterized sound source. When any microphone channel exhibits the expected stimulus, its corresponding "-" becomes a "+":

MICROPHONE	1	2	3	4	5	6	7
HEALTH	+	+	+	-	-	-	+

If all 7 "-"s become "+"s, then all 7 microphones are operating properly:

MICROPHONE	1	2	3	4	5	6	7
HEALTH	+	+	+	+	+	+	+

If any "-"s never becomes a "+", then the corresponding microphone is bad and should be replaced. If replacing the microphone does not fix the problem, then the Boomerang unit must be serviced by authorized repair personnel.

3.8.2 Mode

This button cycles the elevation read out on the LCD display between meters “m” and feet “ft”.

3.8.3 Next/Prev

These buttons are not currently implemented/used. *Future functionality may include the ability to select the parameter to adjust, when in parameter-adjusting mode.*

3.8.4 +/-

These buttons allow the operator to scroll through previous shot detections recorded since this the unit was last turned on.

3.8.5 Dim

This button cycles all display illumination: Bright, Dim, and Dimmer. At power-up, the display is always set to “brightest”.

Bright: LCD backlight on, buttons and LEDs bright

Dim: LCD backlight on, buttons and LEDs dim

Dimmer: LCD backlight off, buttons and LEDs dim

3.8.6 Mute

This button mutes the speaker output. When muted, the Alphanumeric Display indicates “MUT” audio status as shown below:

VEH _____ NNW
RG ___m EL ___m **MUT**

The influence of this control over the gunner headphone output is currently unspecified. At power-up, the speaker is always un-muted.

3.9 Data/Power

The Data/Power connector & cable is 16 pin/conductor arrangement. A right-angle connector at the display end of the cable provides increased display mounting flexibility. shielded conductors are used, as follows (conductor numbers used here do not reflect actual connector pin numbers):

4. Operation

4.1 Powering the System On/Off

The system draws power from the vehicle batteries. There are two power switches. One power switch is located on the side of the Signal Processing Unit as shown in Figure 8. The Signal Processing Unit is located under the right rear passenger seat. The other power switch is located on the topside of the display as shown in Figure 9. The Display is mounted to the vehicle dash. Both switches must be in the ON position for the system to operate.

To turn the system on, first turn the power switch on the Signal Processing Unit from the OFF to the ON position. Then turn the the power switch on the Display from the OFF to the ON position.

The system can be shut down by moving either the power switch on the display or the power switch on the Signal Processing Unit from the ON position to the OFF position.

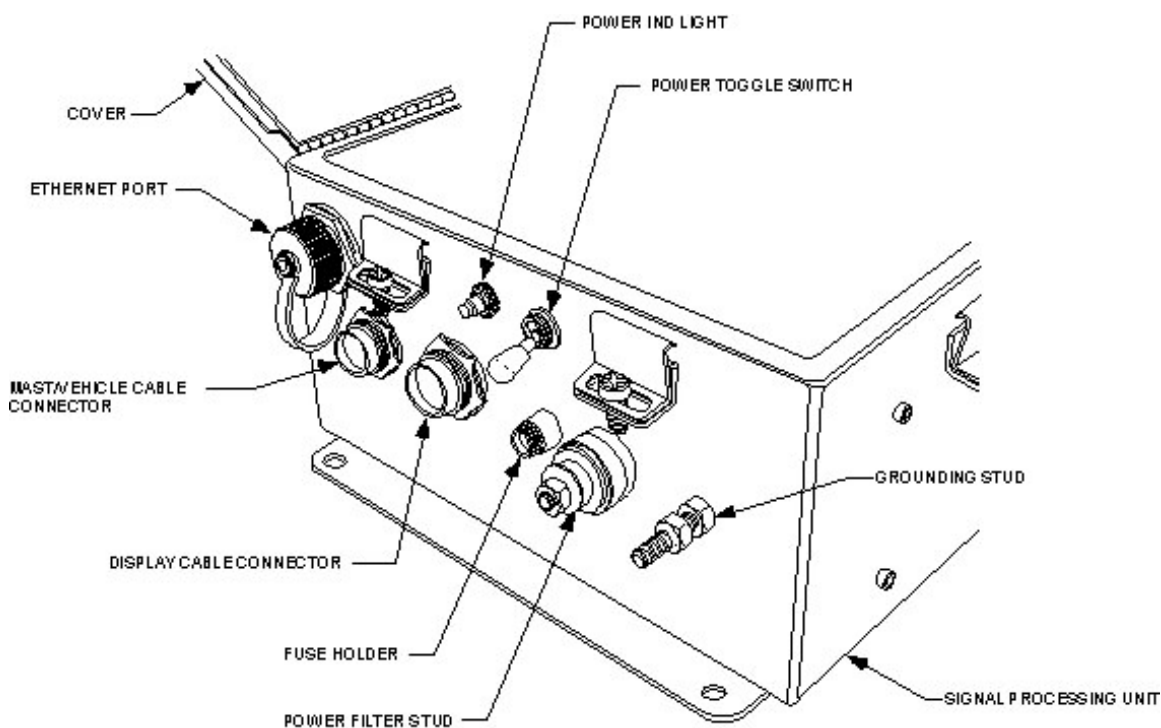


Figure 8: Boomerang Electronics Box showing power switch, power indicator light, fuse, and cable connectors.

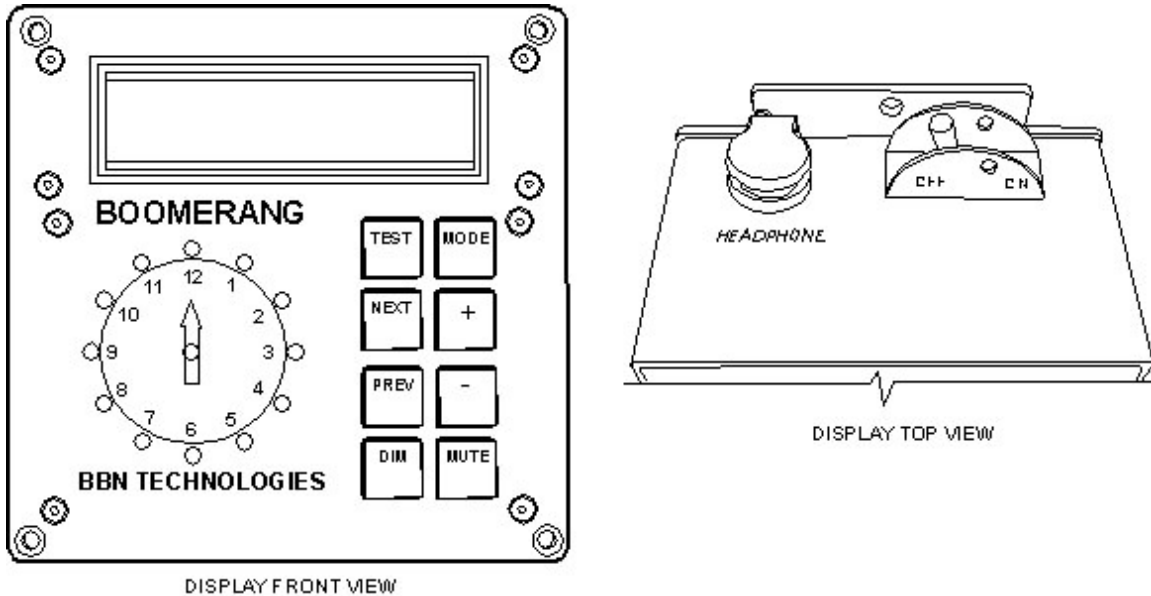


Figure 9: Boomerang Display showing front display, headphone jack and power switch

4.2 Start Up

When the system is initially started, the Alphanumeric Display indicates:

“BOOMERANG

By BBN”

With the center light illuminated

After several seconds an audible beep is heard.

After the beep, the display will show:

“Booting”

“Build (Version of Code)”

Then the following will scroll back and forth on the LCD coincident with the LED ring of lights lighting up sequentially.

Once the system is full operational, the center light of the LEDs will remain illuminated and the LCD will display:

“VEH.”

“GPS”

“RG.....m”

“EL....m”

When the system is in the operational state:

- 1) While no shot has been detected, all shot-related data are “-“
- 2) When the speaker output is muted via the Mute button, “MUT” also appears on the bottom line of the display.
- 3) If no GPS lock is available, then “No POS” is displayed in place of all grid coordinates. If no GPS is attached or the GPS is not functioning properly, “No GPS” will be displayed.
- 4) “Vehicle heading” and “shooter grid coordinates” are included among these descriptions. Both are best determined using a magnetic bearing (digital compass), which is not currently included in the Boomerang hardware, but is an anticipated enhancement. For the short term, vehicle heading will be determined using GPS while the vehicle is underway; and Shooter grid coordinates will not be provided.
- 5) The system always starts with the speaker un-muted and the display at full brightness.
- 6) There are two possible error messages:
 - “No Mic Data” No data being received from hub.
 - “Bad Mics _ _ _ _ _” Indicates microphones that are not operating properly.
 - To clear the error message, press the “MODE” button.

5. Detection

When a gunshot is detected, the Rosette and Alphanumeric Display change to indicate the azimuth, range and elevation of the shooter, correspondingly. The display remains in this state for 30 seconds or until another shot is detected, whichever is sooner. A corresponding announcement is also made via the loudspeaker: “Shot x-o’clock, xxx meters! Shot x-o’clock, xxx meters!”, where the xxx meters value is the range to the shooter, and is given to the nearest 10 meter increment. If a shot is detected but the shooter cannot be localized, then the center indicator of the Rosette blinks, all shooter display values are set to “???” and the corresponding announcement is “Shot! Shot!”

Ambiguous shots are called out as “Shot x-o’clock or y-o’clock” and displayed with two LEDs on the Rosette. The data for only the most likely solution is displayed on the Alphanumeric Display.

The system detects small-arms fire traveling toward the vehicle for bullet trajectories that pass within approximately 30 meters of the vehicle, and from a range of 50-150 meters inclusive. Solutions for bullet trajectories and ranges not within those parameters may be detected, although solutions may become less accurate.

Detections and shooter positions are determined in less than 50 milliseconds. The system resets, and will detect and announce a following shot in one second. False shot detections will be less than one per thousand hours of system operation at vehicle speed under 50 miles per hour. Missed shots will be less than one per 500 shots at vehicle speeds over 50 miles per hour.

The system is calibrated to detect the 7.62x39mm round, which is the round fired by the AK-47 and similar small arms. This round belongs to the family of 30-caliber rifle rounds, and travels supersonically when fired from a rifle. However, this calibration does not preclude the system from detecting larger and smaller rounds, and in fact the system has been tested also with 5.56 NATO and .50 BMG (.50 caliber) rounds, and has performed satisfactorily.

5.1 General

The system indicates the relative position of the shooter both aurally and visually, in one of the twelve clock-hour positions (clockwise from front of vehicle when viewed from above). When on occasion the system can narrow the location of the shooter no further than one of two locations, it will indicate both. The first direction announced is the more probable.

5.2 Aural Indication

The system announces shot detection and shooter relative position by voice from a speaker, in the manner “Shot 3 O’clock”, or in the case of two possible positions, “Shot 3 o’clock or 6 o’clock”. When two solutions are given, the first one is the more probable.

5.3 Visual Indication

The system indicates shot detection and shooter relative position by means of a glowing spot on a visual “clock” face. In the case of two possible positions, both are indicated by glowing spots. The visual indication persists for 10 seconds, unless other shots are detected sooner. In addition the azimuth bearing, range and elevation are reported on an alphanumeric LCD display as shown below:

AZ 168 deg 1234567890 NNW
RG 123m EL _23f+ MUT