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K-77-G2 Long-Range Automotive Radar User Manual

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Revision History

Release Version	Date	Authors	Notes
1.0	November 15, 2023	Edward Ding	Initial draft
1.1	June 24, 2024	Edward Ding	Updated under Ainstein document standardization

⚠ WARNING

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NOTICE

All images shown in this manual are for illustrative purposes only and may not be exact frepresentations of the actual product ordered. Features may not be exactly the same. Due to product improvements or changes in specifications, and in order to improve user experience, all instructions in this manual are subject to change without notice.

Table of Contents

1 Overview

The K-77-G2 Long-Range Automotive Radar is a 77 GHz medium and long-distance automotive millimeter wave radar that is designed for Advanced Driver Assistance Systems (**ADAS**) and autonomous driving applications. Using a Frequency Modulated Continuous Wave Radar (**FMCW)** algorithm, the K-77-G2 is able to measure the range, velocity, azimuth, and elevation of a tracked object in a multitude of different environments allowing for safer roads and better driving where the K-77-G2 is integrated. The radar's primary output is detected objects and radar status.

This manual includes technical specifications, installation instructions and requirements, and relevant precautions to ensure the successful use of the K-77-G2 Long-Range Radar. This manual should be read and followed by technical or engineering personnel to provide better understanding of the product and to aid in initial startup and installation of the radar to their systems.

For more information on user configuration and development options, please refer to the **K-77-G2 Development Guide.**

Please pay close attention to any warning information, as well as additional warnings and notices throughout this manual, as well as information contained in **Appendix B** to this Manual.

2 Specifications and Features

2.1 Radar Specifications

Parameter	Value
Frequency Transmission Range	76 ~ 77 GHz
Power Consumption	<4 W
Operating Voltage	9 ~ 16 V
Operating Temperature	-40° C - 85° C
Ingress Protection	IP69K
Detection Range	0.5 m ~ 200 m
Range Accuracy	±0.4 m
Range Resolution	0.8 m
Velocity Coverage	-200 kph ~ 100 kph
Velocity Accuracy	0.15 kph
Velocity Resolution	0.46 kph
Azimuth Field of View	±45°
Azimuth Accuracy (Boresight)	0.3°
Azimuth Resolution	4.5°
Elevation Field of View	±15°
Cycle Time	~66 ms
Dimensions	63 mm * 72 mm * 18.6 mm

Table 1. K-77-G2 Long-Range Automotive Radar Specifications

Azimuth	Passenger Car RCS (10dbsm, 10m^2	Motorcycle RCS (5dbsm, 3m^2)	Moped RCS (0dbsm, 1m^2)	Pedestrian RCS(~7dbsm, 0.2m^2)
0°	200m	170m	125m	85m
±10°	170m	140m	105m	71m
±20°	142m	120m	88m	60m
±30°	85m	72m	53m	36m
±45°	35m	30m	22m	15m

Table 2. Radar Detection Ranges for Common Objects

2.2 Features

The K-77-G2 Long-Range Automotive Radar includes many unique features that allow it to assist in multiple different automated vehicle systems. Such systems include, but are not limited to **Automatic Emergency Braking (AEB), Forward Collision Warning (FCW),** and **Adaptive Cruise Control (ACC).** Unique features of the K-77-G2 Long-Range Automotive Radar are detailed in this section.

2.2.1 RFCMOS Technology

The K-77-G2 uses an advanced integrated circuit known as RF CMOS (Radio Frequency Complementary Metal-Oxide Semiconductor), which combines the technologies of RF (Radio Frequency), analog, and digital electronics for wireless communication. This, alongside a proprietary hardware signal processing acceleration algorithm, allows for the K-77-G2 to rapidly respond and adapt to changing road conditions and environments.

2.2.2 Highly Adaptive Algorithm

The K-77-G2's proprietary algorithms and signal-processing computing platforms allow for customization for different preferred environments of operation. Faster object tracking, alongside increased capacity of tracking, allows the K-77-G2 to function even in highly cluttered environments.

2.2.3 ADAS Compatibility

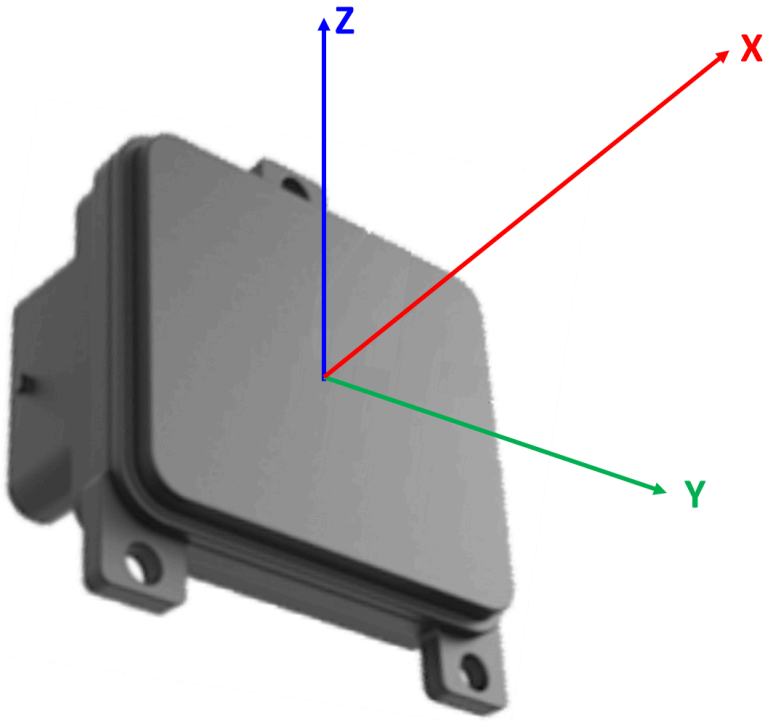
The K-77-G2 is compatible with any passenger car ADAS system that follows the 4+1 solution model (radars mounted at the left and right of both the rear end and front end of the car, with one final radar in the middle). The K-77-G2 is intended to act as the front-center radar in such installations (+1 in the 4+1).

2.2.4 Communication Interfacing

The K-77-G2 supports Controller Area Network (CAN) for all communication with the device. The public CAN bus supports standard CAN (ISO-11898) and the private CAN bus supports CAN-FD (ISO-11898-1) . The K-77-G2 supports UDS diagnostics over CAN.

2.2.5 Tracked Objects in Cartesian Coordinates

The K-77-G2 tracks targets using the standard sensor coordinate frame as set by *ROS REP 103 - Standard Units of Measure and Coordinate Conventions.* All communication interfaces are set with x forward, z up, and y left to complete a right-handed frame.



3 Installation Instructions

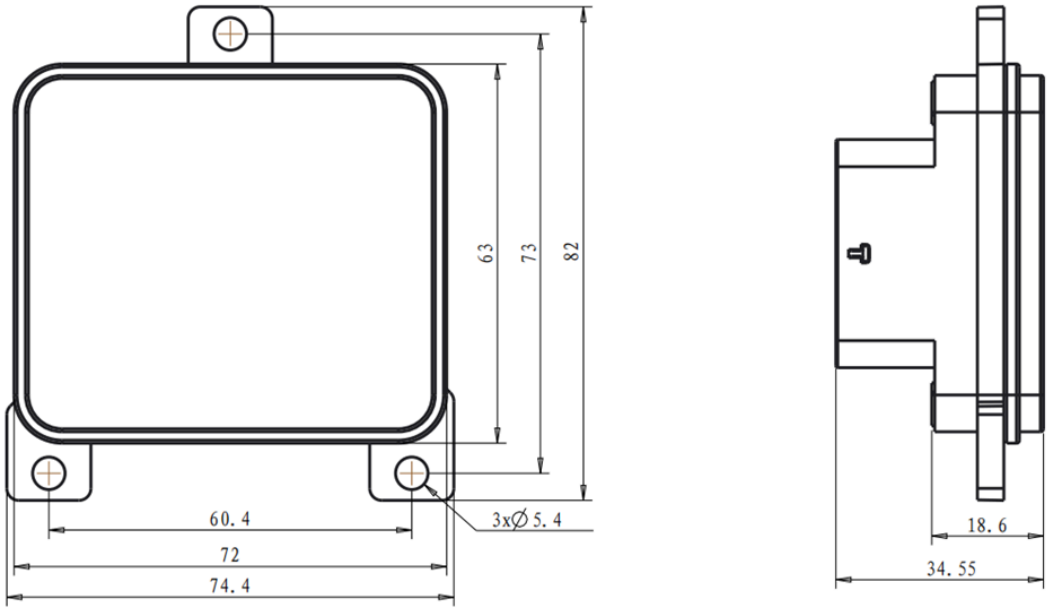


Figure 1. K-77-G2 Long-Range Automotive Radar Mechanical Drawing

This chapter describes the process of installing the K-77-G2 for use in ADAS systems that follow the 4+1 solution model. Details regarding the installation positions, as well as location and environmental tolerances are detailed in the following section

⚠ WARNING

The procedures described in this chapter must be complied with to ensure that the radar functions as intended. Precise measurement checks may be necessary to verify proper installation. Failure to do so may result in inaccurate results which could lead to serious bodily injury or death.

⚠ WARNING

The radar is not designed to be used as a step, handle, or hand hold. Using the radar as either a foothold or handhold may result in damage to the radar that can impede its ability to properly detect and track objects which could lead to serious bodily injury or death.

⚠ WARNING

Wiring work should not be conducted while the power is ON. Turn OFF all sources of power to the radar and relevant equipment prior to any inspection. Failure to do so may damage the equipment and result in serious personal injury or death.

3.1 Cable and Connector Information

The radar interface and connector information are shown in the tables and figures below.

Supplier	Connector Type
TE	C-1-1719393-E-3D

Table 3. Connector Information

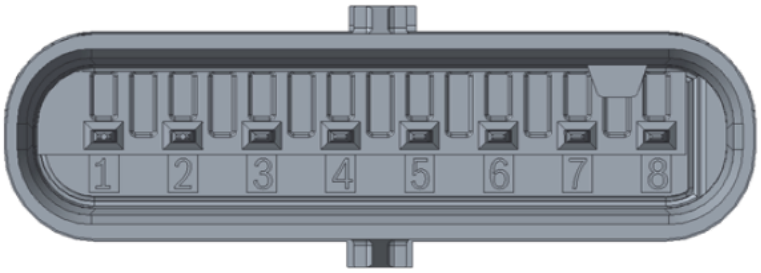


Figure 2. Radar Interface

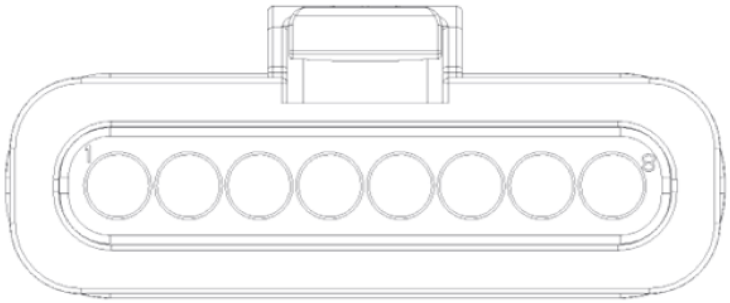


Figure 3. Cable Interface

Pin Number	Pin Definition
1 (Silver)	RESERVED
2 (Orange)	RESERVED
3 (White)	CAN2 L (PRIVATE)
4 (Green)	CAN2 H (PRIVATE)
5 (Black)	GND-IN
6 (Blue)	CAN1 L (PUBLIC)
7 (Yellow)	CAN1 H (PUBLIC)
8 (Red)	DC-IN

Table 4. Pin Definitions

3.2 Mounting and Installation Procedure

NOTICE
When installing the radar, the installation location and calibration method of the radar may differ depending on the intended vehicle model.

The K-77-G2 should be applied to the forward position on the 4+1 ADAS application. The proper positioning for such installation is shown in the figures below. Figure 4 provides a frontal view of the radar mounting position while Figure 5 provides the position as seen from above.

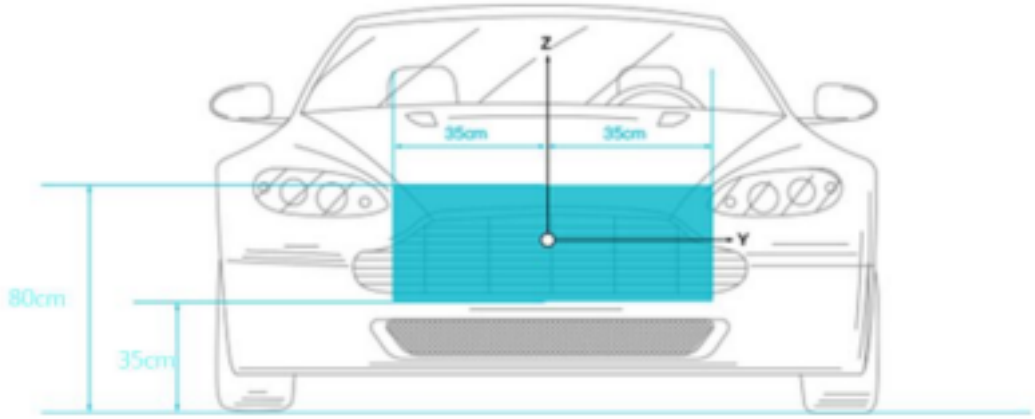


Figure 4. Frontal view of radar position (outlined in green)

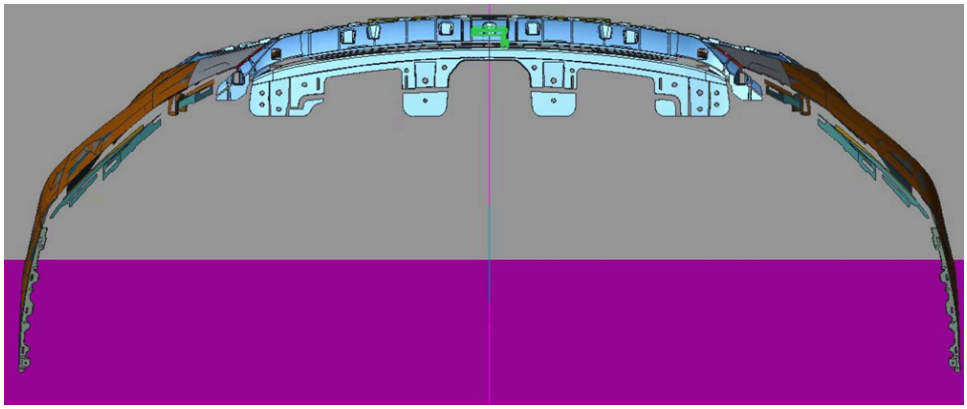


Figure 5. Mounting position when viewed from above (outlined in green)

Ainstein recommends that the K-77-G2 be installed at a maximum distance of 35 cm from the vehicle center and at a height range of 30 - 80 cm from the road surface. If it is necessary for the sensor to be installed outside of these parameters, it should be no more than 10 cm in excess of either parameter (a maximum of 45 cm horizontally from the vehicle center, and a maximum of 90 cm from the road surface level). Exceeding these limitations is likely to hinder the performance of the radar and result in under or over-detection. If the vehicle the K-77-G2 is being installed to has requirements for wading, ensure that the radar is installed above the wading altitude line.

The angular mounting tolerances for the sensor are detailed in **Table 6** below.

Angle	Tolerance (°)
Yaw	±3°
Pitch	±2°
Roll	±2°

3.3 Power Specifications

The K77 Long-Range Automotive Radar is powered by a 12V DC power supply. The operation modes for section voltage are shown in Table 5.

Voltage	Operative Designation	Behavior
<6.5V	Safe	No communication on vehicle interface Restricted fault monitoring (low voltage)
Between 6.5V and 9V	Low-Voltage	Normal communication on vehicle interface Normal hardware monitoring Fault monitoring (low voltage)
Between 9V and 16V	Normal	Normal communication on vehicle interface Normal hardware monitoring Full fault monitoring
Between 16V and 18V	High-Voltage	Normal communication on vehicle interface Normal hardware monitoring Fault monitoring (overvoltage)
Over 18V	Safe	No communication on vehicle interface Normal hardware monitoring Restricted fault monitoring (overvoltage)
Monitoring Tolerance ± 10%		

Table 5. Voltage Supply Operation Modes

3.4 Environmental Limitations

While the K77 Long-Range Radar features a robust and resilient design, there are still limitations with respect to the environments in which the sensor will function. To ensure proper function and object tracking, please ensure that the conditions detailed below are properly maintained. Operating outside of these limitations may impede or fully prevent the function of the radar.

3.4.1 Temperature Tolerance

The K77 Long-Range Radar is intended for use in ambient temperatures ranging from -40 °C to 85 °C. To ensure optimal results, it is recommended to use the radar within this specified temperature range.

3.4.2 Debris and Buildup

If excessive build-up of mud, dirt, or general debris occurs on or around the radome and antenna areas, the radar will experience performance degradation. The radome must be kept clean and free of debris at all times. Ainstein recommends that the user mount the radar in a position where it is unlikely to accumulate debris. However, if the radar needs cleaning, see **Appendix A** for instructions.

4 Automatic Alignment

The K77 supports detecting and correcting for installation angle errors in the azimuth plan during operation. The installer must use a suitable installation procedure to ensure that the radar is installed within the specifications listed above, and the radar's automatic alignment feature will fine tune the output to ensure accurate results.

The automatic alignment feature will run and apply compensation for installation errors in the azimuth direction to within the specification listed in **Table 6** whenever the radar detects the driving conditions listed in **Table 6**. The resulting compensation angle can be monitored via CAN message - see the following section for details.

Automatic Alignment Specifications		
Azimuth Correction	Accuracy	0.5°
	Range	±5°
Driving Requirements	Radius of Road Curvature	> 1000m
	Vehicle Acceleration	< 2.5m/s^2
	Vehicle Speed	>25kph

Table 6. Calibration Specifications

5 Radar Input and Output

K-77-G2 has two CAN buses: private CAN and public CAN. Their functionality is as follows:

Public CAN

- Firmware updates
- UDS - reading and writing DID's, etc.
- Vehicle data sent by the host to the radar - vehicle speed, yaw rate, etc.
    - Can be sent over Private CAN instead

Private CAN

- Objects and/or point cloud reported by the radar
- Vehicle data sent by the host to the radar - vehicle speed, yaw rate, etc.
    - Can be sent over Public CAN instead

The default CAN-FD parameters for the private CAN radar output are 500k-2M baud. The default baud rate for the public CAN is 1M baud. These are configurable upon request. All messages sent by the radar use big-endian byte order. A dbc file for the messages described in this section, which includes detailed message parsing information, is available upon request.

The radar sends information on the private CAN bus periodically. These messages are summarized in Table 7. As shown in Table 7, the radar outputs 40 tracked object messages every 50 ms. These objects are referred to as "Ak", which stands for after Kalman filtering. Each Ak object is described by two CAN-FD messages: a part 1 (P1) and a part 2 (P2) message, the contents of which are tabulated in Table 8 and Table 9. An Ak Status message is also sent every 50 ms, the contents of which are tabulated in Table 10.

The radar reports the result of its internal installation angle calibration every 100 ms, with message contents tabulated in Table 11.

Message Name	Number of Messages	ID	Type	Period
Ak Part 1	40	0x50 + object number, starting from 0	CAN-FD	50 ms
Ak Part 2	40	0x20 + object number, starting from 0	CAN-FD	50 ms
Ak Status	1	0x80	CAN-FD	50 ms
Installation Calibration Result	1	0x468	Standard CAN	100 ms
Frame ID	1	0x480	Standard CAN	100 ms

Table 7. Periodic CAN Messages

Signal	Description	Unit
FRS_P1_xx_Obj_ID	0x00-0xFE: unique identification number over the lifetime of the object. 0xFF: invalid	NA
FRS_P1_xx_Obj_XPOS_stdev	Estimated 3-sigma standard deviation value of the longitudinal position of the object.	m

Signal	Description	Unit
FRS_P1_xx_Obj_updateFlag	Object history flag 0x0: new object in the cycle; 0x1: object existed in previous cycle	NA
FRS_P1_xx_Obj_YPOS_stdev	Estimated 3-sigma standard deviation value of the lateral position of the object.	m
FRS_P1_xx_Obj_ValidFlag	0x0: Object invalid 0x1: Object valid	Na
FRS_P1_xx_Obj_obstacleProb	Estimated probability of the object being an obstacle.	%

Signal	Description	Unit
FRS_P1_xx_Obj_MotionPattern	Object Motion: 0x00: Unknown 0x01: Stationary 0x02: Stopped 0x03: Moving 0x04: Crossing 0x05-07: reserved	NA
FRS_P1_xx_Obj_XAccRel	Relative longitudinal acceleration of the object	m/s^2
FRS_P1_xx_Obj_XAccRel_stdev	Estimated 3-sigma standard deviation value of the relative longitudinal velocity of the object.	m/s^2
FRS_P1_xx_Obj_AliveCounter	Alive counter shall be incremented every radar sensor measurement cycle.	NA

Signal	Description	Unit
FRS_P1_xx_Obj_exstProb	Estimated existence probability of the object.	%
FRS_P1_xx_Obj_checksum	Check sum	NA

Table 8. Ak Part 1 Object Information Definitions - 0x50 + object number

Signal	Description	Unit
FRS_P2_xx_Obj_XVelRel	Relative longitudinal velocity of the object.	m/s
FRS_P2_xx_Obj_YPos	Position of object object in lateral direction	m
FRS_P2_xx_Obj_Type	0x00: Unknown 0x01: 4 wheeler 0x02: 2 wheeler 0x03: Pedestrian	NA
FRS_P2_xx_Obj_XPos	Position of object object in longitudinal direction	m
FRS_P2_xx_Obj_AliveCounter	Alive counter	NA
FRS_P2_xx_Obj_MeasFlag	0x0: object measured in this cycle 0x1: object extrapolated in this cycle	NA

Signal	Description	Unit
FRS_P2_xx_Obj_YVelRel	Relative lateral velocity of the object	m/s
FRS_P2_xx_Obj_Checksum	Check sum	NA

Table 9. Ak Part 2 Object Information Definitions - 0x20 + object number

Signal	Description	Unit
FRS_Latency	Radar process latency in ms	ms
FRS_TimeStamp	Sensor internal timestamp	s
FRS_HostSpeed	Host vehicle over-ground speed	m/s

Signal	Description	Unit
FRS_Status_BlkProg	Sensor blockage status indication. 0x0: FRS is NOT blocked 0x1: FRS is blocked	NA
FRS_Fail	0x0 = FRS radar is NOT working 0x1 = FRS radar is working	NA
FRS_MeasEnabled	This signal indicates if the radar sensor is performing measurement or not.	NA
FRS_Host_Yaw	Host vehicle yaw rate in deg/s	deg/s
FRS_Msg_AliveCounter	Alive counter	NA

Signal	Description	Unit
FRS_ Status_MisAlign	This signal indicates radar sensor mis-alignment status. 0x00:unknown 0x01:calibrated 0x02:sensor mis-alignment detected 0x03:calibration in progress 0x04:uncalibratable 0x05-07: reserved	NA
FRS_ Status_HWerr	Flag to indicate if HW has failed or not. 0x0:HW is NOT failed 0x1:HW is failed	NA
FRS_Msg_CheckSum	Check sum	NA

Table 10. Status Information Definitions - 0x80

Signal	Description	Unit
ActiveCalibrationAngle	Angle compensation currently being applied to the radar data to account for azimuthal tilt due to the radar installation.	deg
LastCalibrationAngle	The last azimuthal installation error compensation angle calculated by the radar	deg

Table 11. Calibration Result Definitions - 0x468

Signal	Description	Unit
akFramID	Ak target frame ID - free running counter	count
bkFramID	Bk target frame ID - free running counter	count

Table 11. Calibration Result Definitions - 0x468

Appendix A – Maintenance

The user is responsible for ensuring that the radome remains clean and unobstructed while the radar is in use, as noted in **Section 3.4.2**.

A mild detergent such as dish soap can be used to clean the unit, if necessary, to remove additional debris that may have attached to the radome during use.

Appendix B – ADDITIONAL WARNINGS, LIMITATIONS, WARRANTIES, and DISCLAIMERS

Ainstein warrants to customer (and customer only) that the product conforms to Ainstein's issued specifications for the product when made. **AINSTEIN MAKES NO ADDITIONAL WARRANTIES,** whether express, implied or statutory, including without limitation any warranty of merchantability or fitness for any particular purpose, whether arising by law or otherwise, or any warranty of or related to any course of dealing, non-infringement of third party rights, course of performance, usage of trade, or otherwise. Customer acknowledges that it has not relied upon any representation or warranty made by Ainstein, or any other person on Ainstein's behalf, except as expressly stated in this paragraph.

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Customer assumes all responsibility for use of the product not in accordance with the directions, instructions and/or terms set forth in this Manual and on the product labels. As such, the customer is responsible for any safety hazards or risk, damages or failures caused by or attributable to use of the product not in accordance with the directions, instructions and/or terms set forth in this Manual and on the product labels.

This product meets the applicable FCC Part 95 rules. Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

NOTICE
To limit RF radiation exposure, please always ensure 8 inches (20 cm) of separation from the device. Users should consult with medical or health care professionals if they have any specific concerns or questions about RF radiation exposure during use of this product.

Industry Canada RSS

English

This device complies with Industry Canada's license-exempt RSSs. Operation is subject to the following two conditions:

1. This device may not cause interference; and
2. This device must accept any interference, including interference that may cause undesired operation of the device.

This equipment should be installed and operated with a minimum distance of **20cm** between the radiator and your body.

Français

Cet appareil est conforme aux RSS sans licence d'Industrie Canada. Son fonctionnement est soumis aux deux conditions suivantes:

1. Cet appareil ne doit pas provoquer d'interférences; et
2. Cet appareil doit accepter toute interférence, y compris les interférences susceptibles d'entraîner un fonctionnement indésirable de l'appareil.

Cet équipement doit être installé et utilisé avec une distance minimale de **20 cm** entre le radiateur et votre corps.

Appendix C - Third Party Licensing Agreements

Commercial Software

No commercial software products or components which require attribution are used for the distribution or use of the K-77-G2

Open Source Software and Separately Licensed Software

Appendix D - Troubleshooting

Problem	Possible Cause	Remedy
Radar doesn't turn on	Faulty power connection	Ensure 12V input is properly applied
Radar turns on but can't communicate over CAN	Incorrect CAN wiring; PC/host interface not initialized	Ensure connection is as described in this manual above, including the termination resistor. Ensure the PC/host CAN interface is working.

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Hours (UTC - 6 / Central Time (CT)):

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