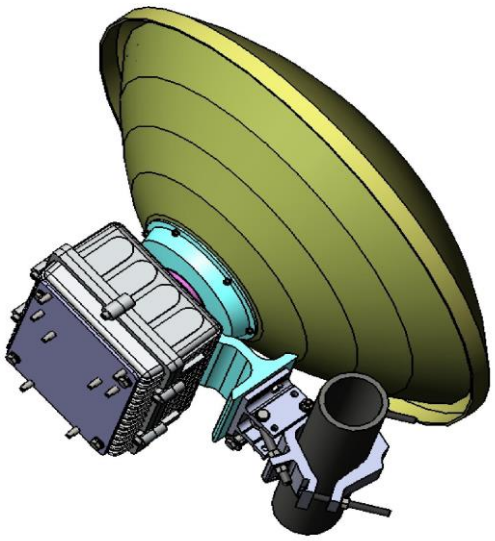
ELVA-1
Millimeter Wave Division

Installation and User Guide

SDM-76 Railway Radar

76.5 +/− 0.15 GHz



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1 SDM-76 RADAR OVERVIEW

SDM-76 is all-weather specialized radar for use on the railway stations for safe train arrival. The radar measures speed and distance of a train or locomotive arriving to deadlock end of exact railway track. SDM-76 is acronym for 76 GHz Speed-Distance-Meter.

By its functionality, this is an analogue of the parking sensor on the auto vehicle. Moreover, SDM-76 radar is based on automotive radar specs, and it works in millimeter-wave band at the frequency of around 76 GHz, which worldwide devoted for license-free applications of automotive cruise control radar. This frequency band of 76 GHz is belonged to W-band, and does not require a license in Europe, USA and many other countries.

Practical use of the SDM-76 requires that each radar has to be connected to train traffic control data center. This is just as well as sensors on the bumper of a vehicle have to be connected to the vehicle computer to inform the driver of an obstacle.

Speed and distance of arriving train are transmitted from data center to dispatcher and locomotive driver, telling them on approaching of the train (or loco) to a deadlock end on the exact track of railway station.

SDM-76 radar can also be used within railway computerized safety system for automatic emergency braking of the train or loco when it approaches deadlock end with an unsafe high speed.

Figure 1: SDM-76 radars controlling railway track deadlock ends.

1.1 Radar Abstract

The design of the radar includes

- Radar unit for measuring speed and distance,
- Cassegrain-type antenna to form a very narrow radiation pattern,
- Alignment mount for fixing the meter on the mast (supporting leg) and precise adjustment of the antenna to the monitored railway track.

Radar control zone corresponds to a circular cone with an angle of about 0,5° and a length of 500 meter (0,3 mile) along the railway track. The radar range is from 1.5 m (1,6 ft) to 500 m (0,3 mile) with max controlled speed of 100 kph (62 mph). The parameters of max controlled speed or distance range could be adjusted according to customer order.

The radar is designed for mounting on a vertical support leg (mast) standing over railway track at the central point between the rails. The mast diameter could vary from 50 mm (2”) to 120 mm (5”) with height not less than 2.15 m (7.05 ft).

Because the radar have no own controls and no display, it is designed to transmit the distance and speed parameters of arriving train to railway Data Center via the Ethernet interface.

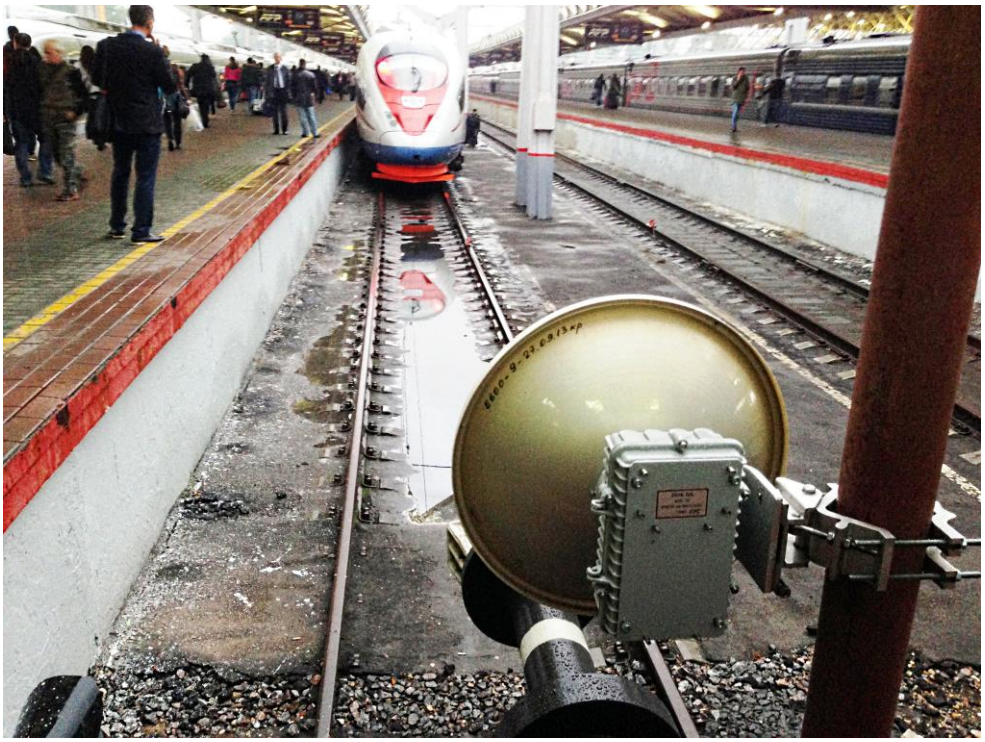

Figure 2: SDM-76 radar at controlling Siemens Velaro hi-speed train arrival to deadlock end.

SDM-76 radar implements the following features:

• Cyclic detection of objects in covered area, such as trains (suburban, high-speed, single loco, etc..), rail repairing machinery, person or group of people, etc .;

• The adjustable range of control zone based on the threshold levels of return signal;

• Measuring distances to objects in control zone, the radial velocity of movement, the power level of signals from objects;

• Distinction of large objects as train/carriage/loco on a controlled track from other objects in this zone like railway personnel, animals, etc. by the level of return signal.

1.2 Radar Dimensions and Specs

The following are radar drawing and specifications. Basic version of radar is shipped with antenna of 60 cm (2 ft) diameter. ELVA-1 could customize the radar specs according to customer requirements, including various antenna size, radar distance range and other parameters.

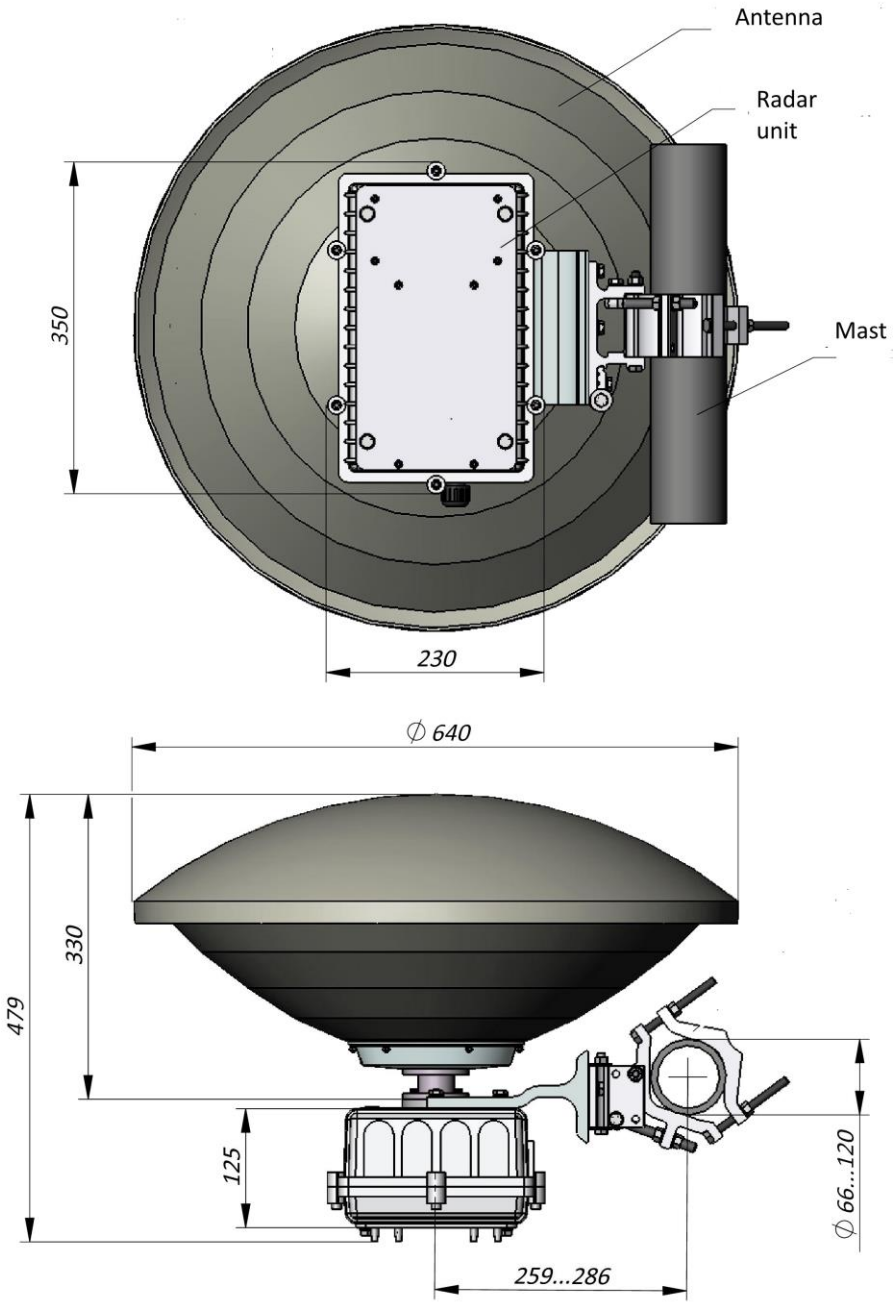

Figure 3: Radar dimensions, shown in millimeters

The 60 cm antenna ensures the desired antenna pattern is as narrow as 4.3 m at the distance of 500m. On the real environment of stations with deadlock end tracks, the length of platforms are usually not more than 500m (500m means circa 20 passenger carriage train). The distance of 500m is also enough to emergency stop of a passenger train from the speed of 60-70 km/h to zero, when the radar operates in the environment of computerized railway safety system with remote breaking capabilities.

SDM-76 radar can be equipped with antenna of diameter from 10 cm to 90 cm, in accordance with requirements of customer for use in a specific project. The larger is the diameter of the antenna, the narrower is the radar beam (also known as antenna directivity pattern) and longer radar range could be.

SDM-76 Specs

Distance measurement range	1.5 – 500 m
The max distance measurement error	+/- 0.25 m
Speed measurement range	1 – 100 km / h
Speed measurement range	max 1.0 km / h
Radar frequency	76.5 +/- 0.15 GHz *
Modulation	FMCW
Output power at Swept frequency modulation	10 mW
Antenna diameter	600 mm
Beam width	0.42 degrees
Diameter of spot at 500 m	4.3 m
Output Interface	100Base-Tx UTP Ethernet
Measurements update time	20 ms
* Consumed electrical power	25/35 W, 18-36 V DC
Environment protection class	IP65
Environment operating temperature , °C	-45 to +55 °C

* When operates at cold weather, the radar automatically activates 10 W heater inside the radar case to keep radar components running reliably. Thus, the consumed power changes from 25 W to 35 W.

2 SAFETY AND WARRANTY

The information in this manual is directed to persons who will perform or coordinate the tasks associated with the process of installing radar, and planning of it communication within railway LAN/WAN network.

This manual assumes the personnel has at least basic experience with and understanding of the concepts underlying radar and LAN systems, as well as some familiarity with configuring and operating networking equipment. Preferably, the installer/operator fully understand the information covered in this manual prior to attempting these procedures.

2.1 Safety Recommendations

SDM-76 radar has very low radiation emission (10 mW) to work at the territory of public spaces like railway station. This 10 mW radiation emission is comparable with ordinary mobile phone emission.

Ultra-narrow beam allows to keep emission pattern within railway track only for distances up to 500 m (0,3 mile) from the radar, not affecting side areas of passenger platforms.

Locomotive drivers are not affected by radiation emission also, as windshield glass and metal of loco cockpit effectively weaken the radar radiation to practically zero.

The following general safety precautions must be observed during all phases of operation and service of the SDM-76 radar. Elva-1 assumes no liability for the customer's failure to comply with these requirements.

- This product is not designed to withstand a direct lightning strike. It should be operated only with the protection of an external lightning rod.
- Do not work directly in front of energized antenna. Before starting any work in front of antenna within 10 m range (33 ft), contact radar operator to remote switch the radar off or to "stand-by" mode with no emission.
- The outdoor equipment must be properly grounded to provide protection against voltage surges and built-up static charges. In the event of a short circuit, grounding reduces the risk of electrical shock.

For installations in the USA, refer to Articles 810830 of the National Electrical Code, ANSI/NFPA #70, for information with respect to proper grounding and applicable lightning protection for DC cables. For installations in all other countries, implement protection in accordance with the safety standards and regulatory requirements of the country where the equipment is to be installed.

- Do not install or operate this equipment in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.
- This product is designed to withstand moisture conditions typically encountered when installed outdoors. This is not designed for operation under water.
- This product should be operated only from the type of power source indicated in manual.

2.2 Product Warranty

Elva-1 warrants each product sold by it to be free of defects in material and workmanship under conditions of normal use for twelve (12) months from date of receipt thereof to Buyer. Repair or, at Elva-1's option, replacement of defective parts shall be the sole and exclusive remedy under this limited warranty. All warranty replacement or repair of parts shall be limited to equipment malfunctions, which, in the sole opinion of Elva-1, are due or traceable to defects in original materials or workmanship.

In the event the Buyer believes that the Product is covered by the limited warranty of this Section, the Buyer shall pay for the shipping and insurance of such Product to Elva-1. If Elva-1 determines in its sole opinion that such Product does conform to the limited warranty, then Elva-1 shall pay for the shipping and insurance of repaired or replacement Product back to the Buyer. However, in the event that Elva-1 determines in its sole opinion that such Product is not covered by the limited warranty, Buyer shall pay for shipping and insurance of such Product back to the Buyer.

All obligations of Elva-1 under this limited warranty shall cease in the event of abuse, accident, alteration, misuse or neglect of the Product. In-warranty repaired or replaced parts are warranted only for the remaining unexpired portion of the original warranty period applicable to the repaired or replaced parts.

REASONABLE CARE MUST BE USED TO AVOID HAZARDS. ELVA-1 EXPRESSLY DISCLAIMS RESPONSIBILITY FOR LOSS OR DAMAGE CAUSED BY USE OF ITS PRODUCTS OTHER THAN IN ACCORDANCE WITH PROPER OPERATING PROCEDURES.

THE FOREGOING LIMITED WARRANTY FOR ELVA-1 PRODUCTS IS EXPRESSLY IN LIEU OF, AND EXCLUDES ALL OTHER EXPRESS OR IMPLIED WARRANTIES, INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY AND OF FITNESS FOR PARTICULAR PURPOSE, USE OR APPLICATION, AND ALL OTHER OBLIGATIONS OR LIABILITIES ON THE PART OF ELVA-1 MILLIMETER WAVE DIVISION, UNLESS SUCH OTHER WARRANTIES, OBLIGATIONS OR LIABILITIES ARE EXPRESSLY AGREED TO IN WRITING BY ELVA-1.

Statements made by any person, including the representatives of Elva-1, which are inconsistent or in conflict with the terms of these warranties shall not be binding upon Elva-1 unless expressly reduced to writing and approved by CIO of Elva-1.

Do not install substitute parts or perform any unauthorized repair or modification to the equipment. Any repair, changes or modifications not expressly approved by Elva-1 void the Warranty on the equipment.

3 RADAR UNPACKING AND ASSEMBLY

3.1 Radar Unpacking

SDM-76 equipment will arrive in 2 boxes, the sizes of which depends on requested antenna diameter.

Figure 4: Radar package

One of the boxes contains the antenna, and the other box contains radar unit, mount (mounting/alignment bracket) and accessories (corner reflector, cables, connectors, tools, etc.). Please mind the package boxes and foam inserts could be vary from illustrated above.

Note. The factory recommends that the shipping boxes and packing materials be retained by the customer at least for the length of the warranty (12 months), or longer.

Please be very careful with antenna dish mirror. Any damage (dent, distortion) of the antenna or its radome will distort the antenna directional pattern. This will lead to radar malfunction. When unpacking, do not put antenna on the table on it radome, — on the contrary, put it on a flange only.

- Unpack the boxes and bring the radar unit, antenna, mount, 6 mounting screws and wrench #7 (7 mm) onto clean table within well-lit room (indoor) for assembling them.

3.2 Assembly of Radar

Place the radar unit on a table on the position of flange up. Remove protective tape from waveguide channel hole on antenna and on radar unit. Be sure waveguide channel orientation on antenna flange and radio case flange are the same (like || but not like +). Rotating antenna flange on any 180 degrees relative to radar unit flange orientation doesn't matter, ↑↓ or ↑↑ is the same.

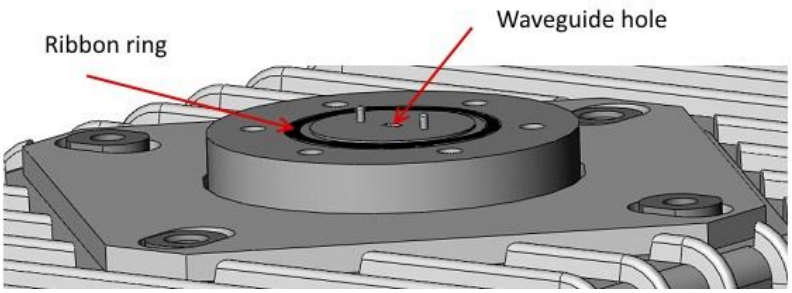

Figure 5: Radar unit on the position of flange up with removed protective tape from waveguide channel hole.

Run visual check that ribbon ring around waveguide channel hole is in place like on Fig. 5 and not damaged.

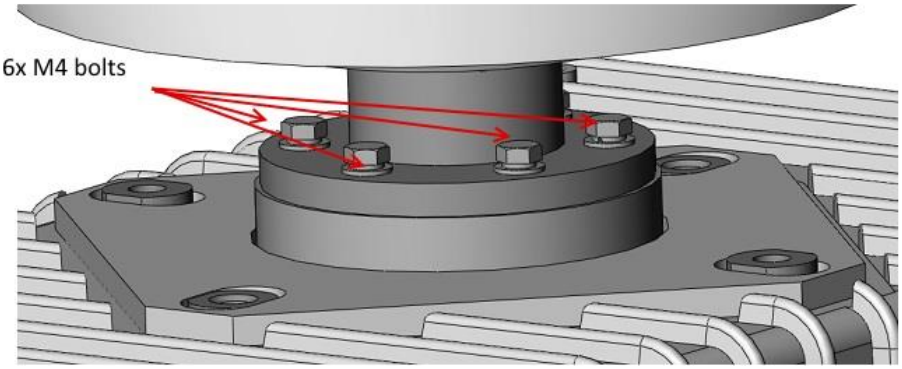

Figure 6: Use 6 x M4 bolts to assemble radar unit and antenna

Fasten the antenna to the radar unit as flange-to-flange.

- Use six M4 bolts with washers (enclosed to the accessories package) to fasten antenna to radar unit. When draw up of M4 bolts, do it cross-wise. The wrench 7mm for M4 bolts is enclosed.
- Avoid of excessive torque [torsional] force for M4 bolts to prevent screw thread on radar unit flange from damage (strip thread). Max torque force for M4 bolts is 2.5 NM.

As the result of your work to fasten antenna to the radar unit, it has to look like shown below.

Figure 7: Radar unit assembled with antenna

3.3 Assemble of Omnidirectional Reflector

Omnidirectional corner reflector is intended to simulate the object (train, loco) during initial adjustment of the direction of radar antenna at the place of installation.

When unassembled, omnidirectional corner reflector consists of four metal plates with slots, six plastic clamps for fixation and anchoring device in the form of clamp for mounting on a portable support leg. Assemble the reflector as structure of the eight corner reflectors oriented in different directions. View omnidirectional corner reflector assembled and mounted on a support, as shown in Fig. 8.

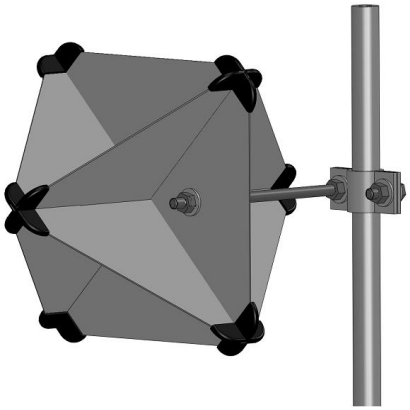

Figure 8: Omnidirectional corner reflector

Note. Supporting leg for omnidirectional corner reflector is not included to the shipment. Use any appropriate portable support leg with height not less than 2.15 m, for example, photography tripod.

4 RADAR INSTALLATION

The radar has to look like on Fig. 9 when installed.

Note. While assemble radar with mount, mind the position of cable sockets on the radar unit case. Communications and power socket should be at the bottom position of radar case, not at top one.

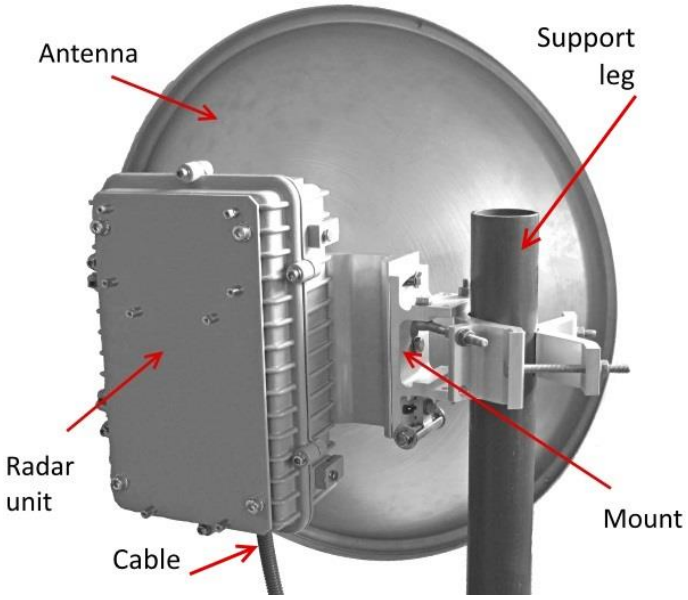

Figure 9: Radar installed on mast with cable socket at bottom position.

4.1 Requirements to Place of Installation

The radar has to be installed onto a vertically mounted support leg (mast) with diameter of 50 to 120 mm (2" – 5") and height of not less than 2.15 m (7.05 ft), located in the deadlock end.

Note. The mast is not included to the shipment. The mast must be resistant to wind load and other fluctuations and should ensure immobility of radar within ± 0,2° in azimuth and elevation. It is prohibited to fix the radar on mast that exposed to swing, shake, etc.

Place of installation of the radar shall satisfy the following requirements:

• The location must be protected from direct mechanical collision with train, locomotive or rail repairing machinery (it is recommended to install the radar behind of last point of railway at deadlock end);

• The radar should be located directly above the center of the controlled railway track;

• The axis of the main lobe of the antenna pattern must be strictly parallel to the railway track;

• The radar must be located behind from the controlled section of railway track at a distance of R1 ≥ 1,5 m to provide a precise measurement of the distance to a train. This distance R1 = 1,5 m (4.92 ft) is optimal and provides the maximum possible length of the controlled section of railway track.

• For the correct operation of the radar at long range it is recommended to install it at a height of H = 2150 mm (7.05 ft) relative to the top point of rail on the railway track;

• The place of installation has to be protected from possible vandalism of general public, while has to be convenient to technicians.

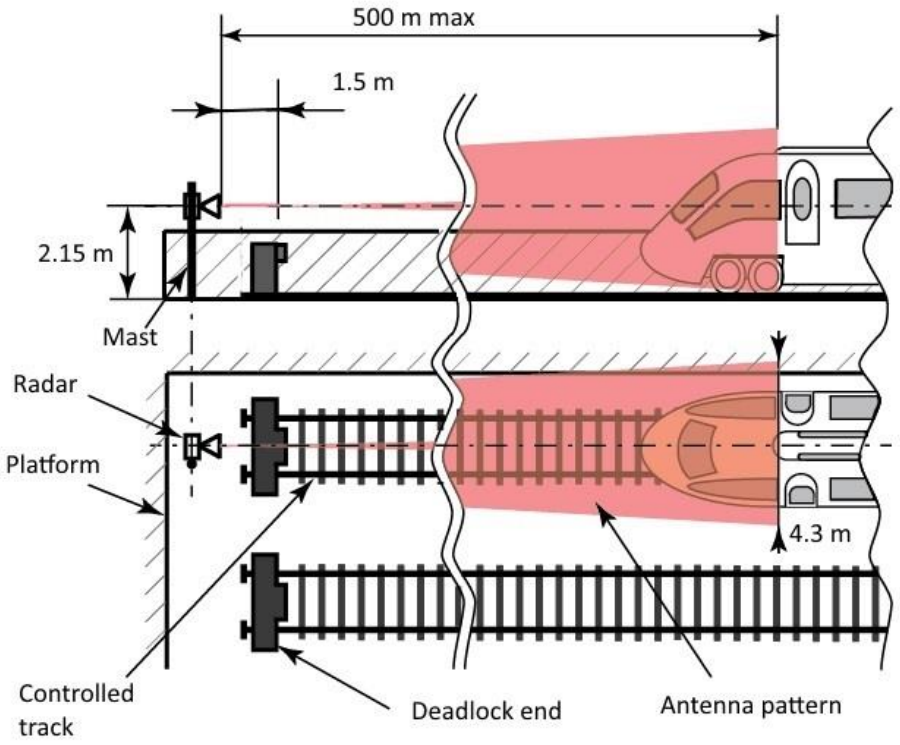

Figure 10: Diagram of radar installation at railway track

4.2 Installing Radar on Mast

Installation of the radar on-site onto mast (or on other kind of supporting leg) includes:

- Fixing of mount with adjustment mechanism on the support leg (mast) at required height;
- Assemble mount and radar as whole device;
- Connecting data cable, power cable and ground wire;
- Alignment of radar antenna to the controlled area of the railway track.

Note. Mount design provides possibility of locating it either the left or right side from the supporting leg (mast). The U-bracket of the mount (see Fig. 11, right) is factory fastened to radar unit by 3 x M8 bolts.

Installing the radar on supporting leg (mast) begins from the installation of mount. The mount consists of a mounting bracket and alignment mechanism.

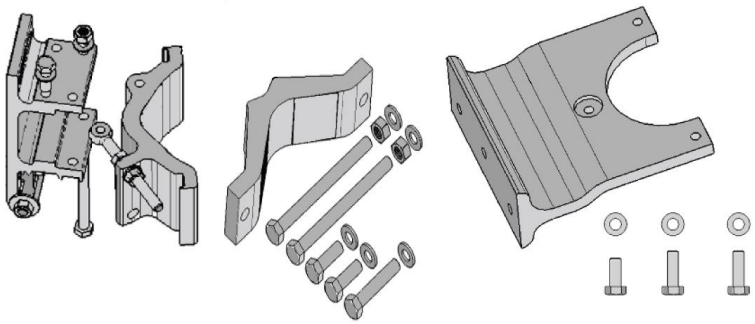

Figure 11: Mount components

Depending on supporting leg diameter, assemble mount as shown on Fig. 12.

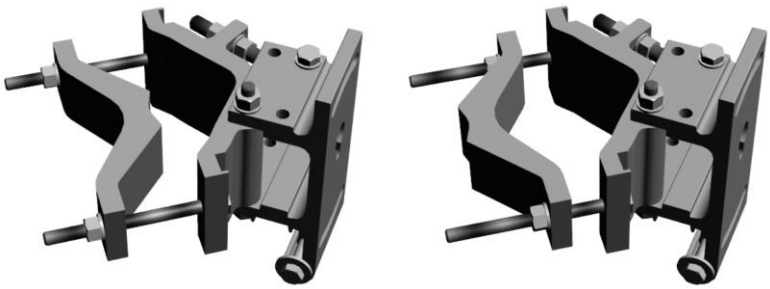

Figure 12: Mount assembled for leg diameter 50-66 mm (left) or 60-120 mm (right).

Put the assembled mount onto support leg from the top of leg and secure it at height 2.15 m. Alternatively, the mount could be put on not from the top, but screw down to the support leg from f side, pre-releasing mounting bracket, and then re-attach it to the mechanism. Bolts of mount should be tightened with little effort, which would allow rotate mount around the support leg by hands for further antenna alignment.

For preliminary guidance in azimuth direction, turn the mount mechanism so, that the upper edge of the receiving plate would be parallel to the rails (see Fig.13). After completing of preliminary alignment, tighten the bolts of mount mechanism to support leg to the final torque of 24 Nm (if you has no torque wrench - tight bolts well enough).

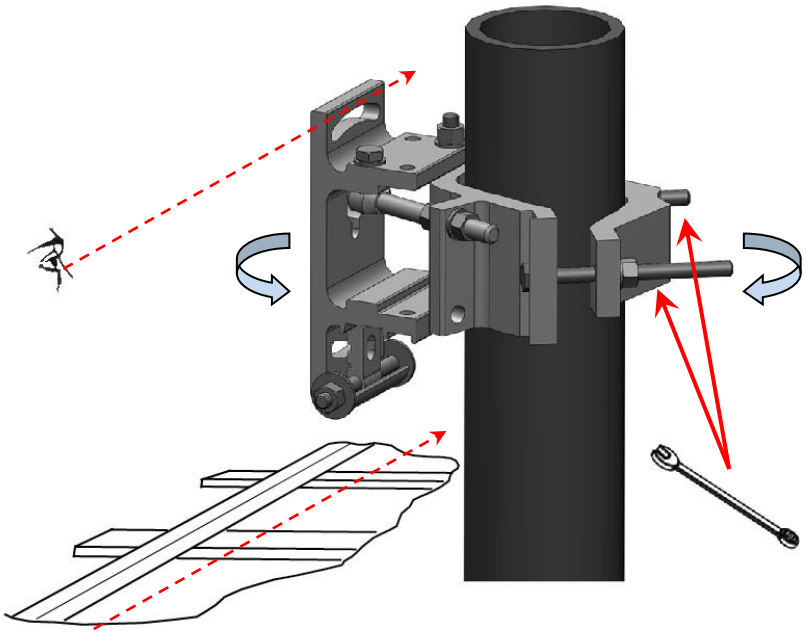

Figure 13: Mount preliminary guidance in azimuth direction.

Screw on M8 bolt from accessories to the middle position at mounting bracket of radar unit. Let the bolt underburned in thread for 10 ÷ 12 mm over bracket like on Fig.14. The purpose of this — to hang on the radar unit assembled with the antenna to this protruding bolt. Washer of this bolt should go beyond the receiving plate, thereby increasing the mounting area of the resulting "hook".

Figure 14: M8 bolt as a hook

• Hang on the radar unit on the middle M8 bolt as on a hook, tighten the upper, middle and lower screws on the receiving plate of the mounting bracket with a little force of about 2 Nm (ie, so that the radar unit could be then rotated to elevation direction at the precise alignment in next steps).

Note. When assemble radar with mount, mind the position of cable socket on the radar unit case. It should be at the bottom position of case, not at top one.

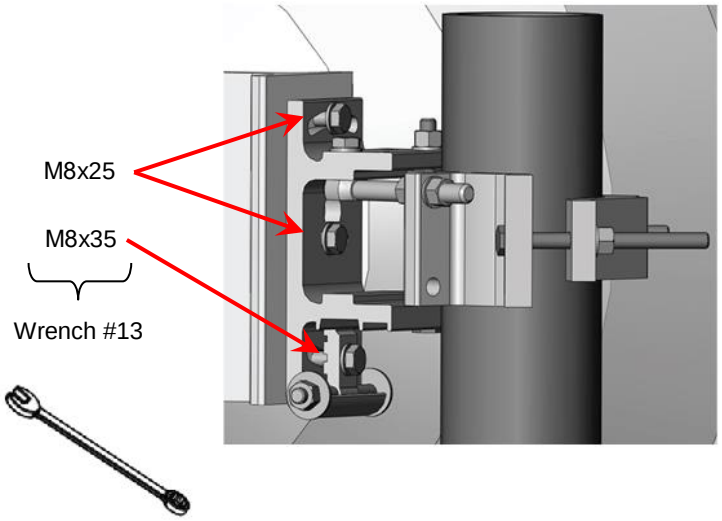

Figure 15: Fixing radar unit case to mount

4.3 Changing the Position of Radar Unit from side of Mount

In case of need to change the position of radar unit to mount from left side to right one or vice versa, do the following:

- Unscrew 2 x M8x20 bolts and 1 x M8x25 bolts at U-bracket on radar unit case.
- Fix U-bracket on radar unit case on opposite side
- Reassemble mount according to Fig. 16.

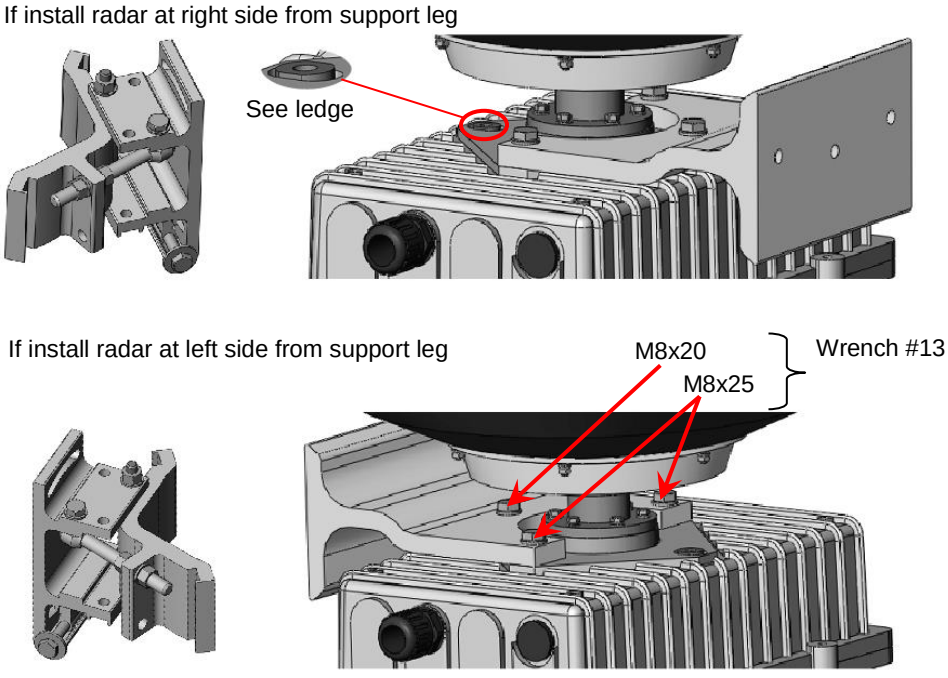

Figure 16: Reassembling U-bracket on radar unit case on opposite side

4.4 Connecting Radar to LAN, Power and Ground

The radar is equipped with 0.5 m length factory sealed hose containing data cable and DC power cable inside as shown on Fig. 16.

Data cable is 4-pair Twisted Pair cat.5 cable with RJ-45 connector. DC power cable is 2-wire low-voltage cable of TAS-C102-1.50 type with solder pins for clamping.

Figure 16: Cable connectors of radar

The radar has to be powered from an 18-36 V DC external power supply unit (PSU). By default, PSU for radar is not included to the shipment, but it could be ordered separately.

Note. DC voltage 18 - 36 V is not dangerous for life and therefore requires no special precautions when handling power cable.

For grounding of radar, use stationary ground wire with not less than 2.5 mm^2 cross-section.

Use any of the threaded areas indicated in Fig. 17.

Figure 17: Radar grounding

Note. Grounding of radar is not sufficient to withstand direct thunderbolt. The radar should be operated only under protection of external lightning rod.

The general diagram of radar connection is shown on Fig. 18.

- Place outdoor cross-connection box nearby of radar.
- Bring UTP cable and power cable from railways stationary cabling to this cross-connection box.

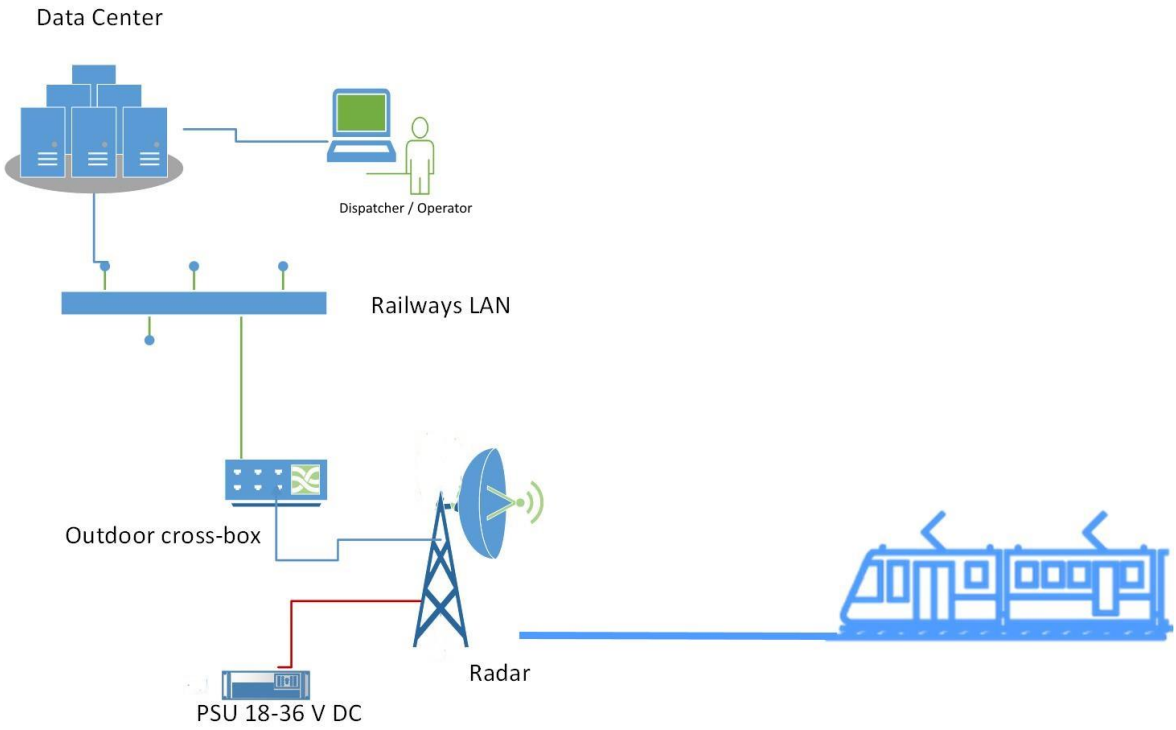

Figure 18: Radar connections diagram

5 FINE-ALIGNMENT AND COMMISSIONING OF RADAR

5.1 Fine alignment of radar

Fine adjustment of radar antenna position is intended to get the axis of the antenna at a height of 2.15m strictly parallel to the controlled section of railway track, while running along the center of the track, as shown in Figure 19. At this figure, antenna axis refers to the main lobe axis.

Precise alignment should be performed at fair weather and good visibility (no rain, no fog or smog, no snow, no sandwind).

For precise alignment it's mandatory to have one technician with laptop at point of radar and another technician equipped with omnidirectional corner reflector at the ground of track. The two-way communication like mobile phones or walkie-talkie radios required to coordinate their work.

The precise alignment is carried out after radar has been installed, connected to the power supply source and laptop with radar software application.

Precise aligning is carrying out according to peak reflection level, displayed on laptop.

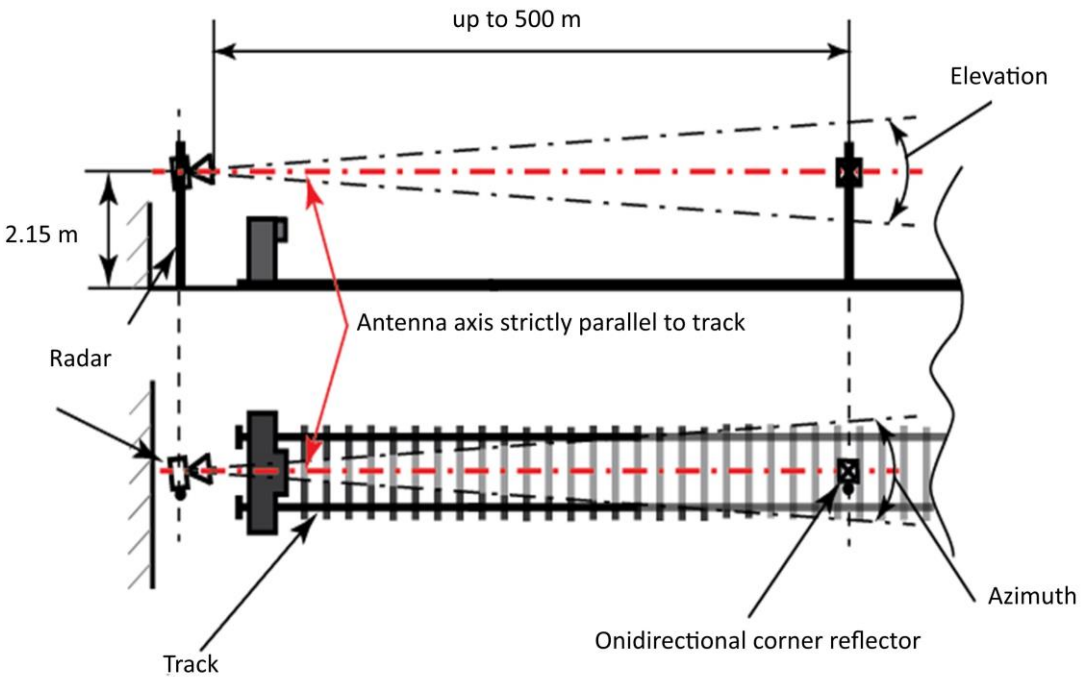

Figure 19: Radar fine alignment diagram

To measure attenuation do the following:

- Connect radar power cable to external 18-36 V DC PSU and switch it ON.
- Connect data cable to LAN socket of laptop working under Windows XP / 7 / 8.1.
- Set IP Address of local machine at 192.168.10.10, netmask 255.255.255.0.
- Connect to Radar module (make sure link up for network adapter of local machine).
- Run tuning software application <radarcapture2016.exe> on laptop.
- Get yourself familiar with application window (Fig. 20)

- Use mouse or laptop pointing pad for setting parameters (click Settings button)
  Setting defaults

Source IP	192.168.10.10
Destination IP	192.168.10.255
Source port	whois++ (63)
Destination port	whois++ (63)
Netmask	255.255.255.0
Source MAC	00:1e:68:ae:76:ff
Destination MAC	ff:ff:ff:ff:ff:ff

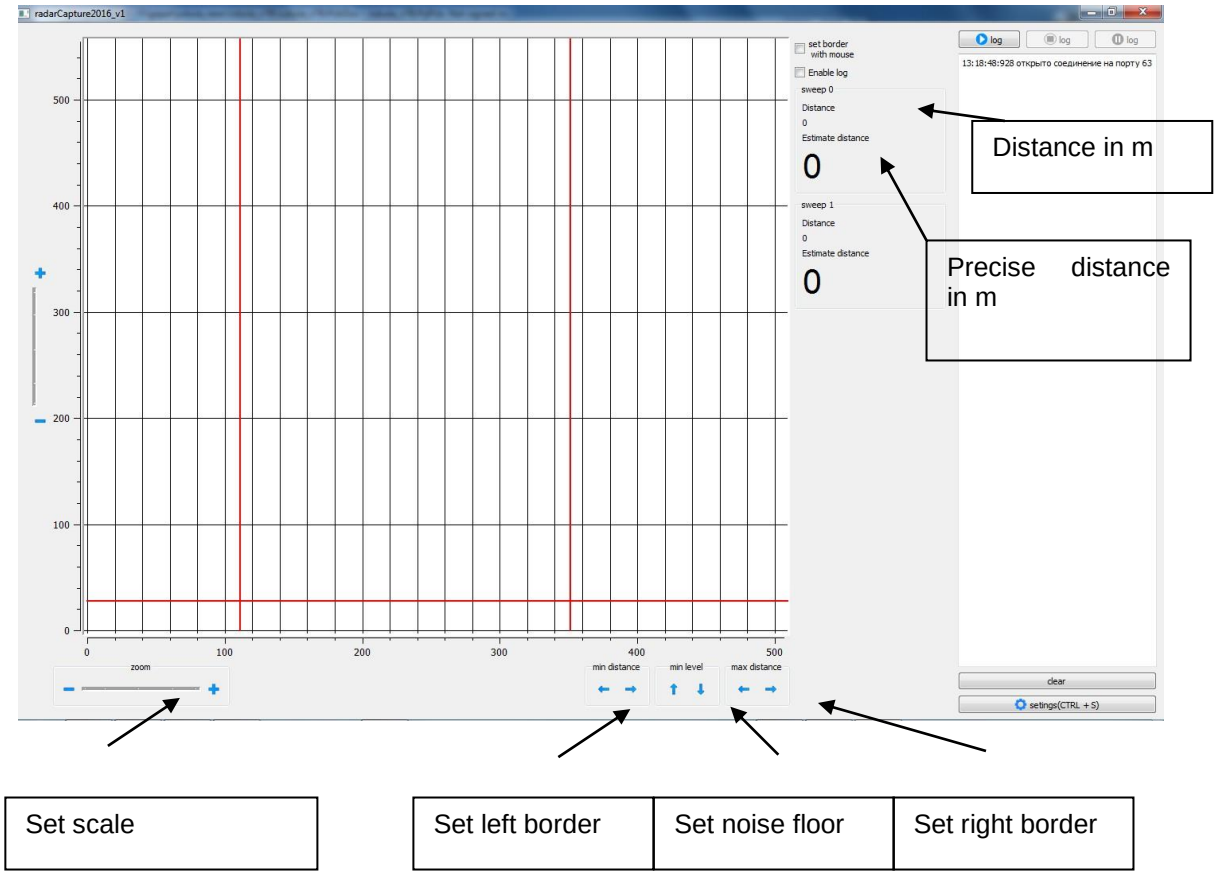

Fig. 20. Window of radarcapture2016.exe application

UDP datagram length 514 bytes

<2 bytes> sweep number and packet number
<512 bytes> data 256 x 2bytes

Full data consist of 4 datagram.

The sensor transfers 2048 FFT harmonics. One harmonics corresponds to 0.15m

- Get omnidirectional corner reflector installed on the portable tripod at distance 500 m (0.31 mile) from radar. This distance could be vary from 500 m, depending on exact length of passenger platform or other local circumstances. The reflector has to be at the same 2.15 m height as radar. To achieve the most effective area of the reflector it is recommended to orient it so that one of its eight corners looks directly back to the radar.
- Get yourself familiar with antenna alignment mechanism to change the orientation of the antenna axis within ± 15 ° in azimuth and elevation (Fig. 21).

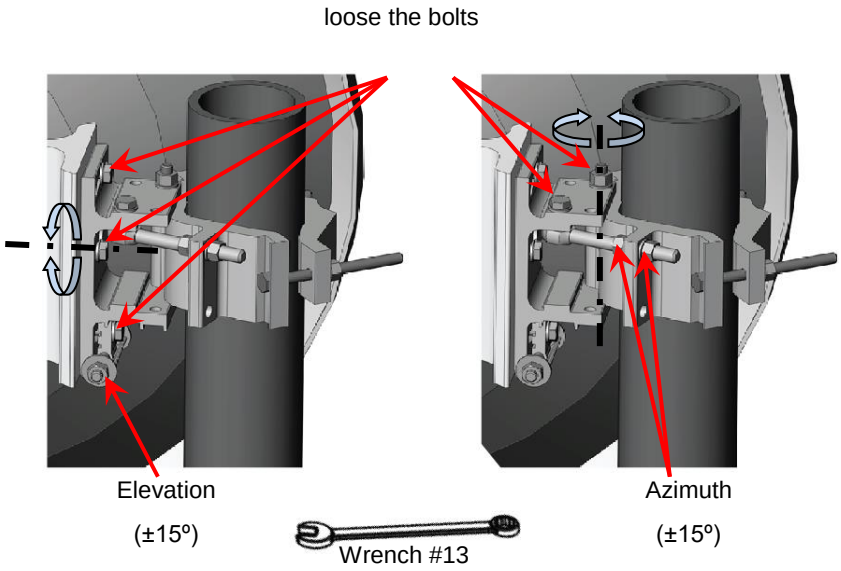

Fig. 21. Elevation and azimuth alignment mechanism

- Check that there are no any false targets on line of sight between radar and corner reflector (third party personnel, machinery, etc) giving reflection comparable to those one from corner reflector.
- Rotate the adjustment mechanism bolts/nuts shown at Fig. 21 and implement antenna beam scan to detect corners reflector as signal peak on the laptop screen.

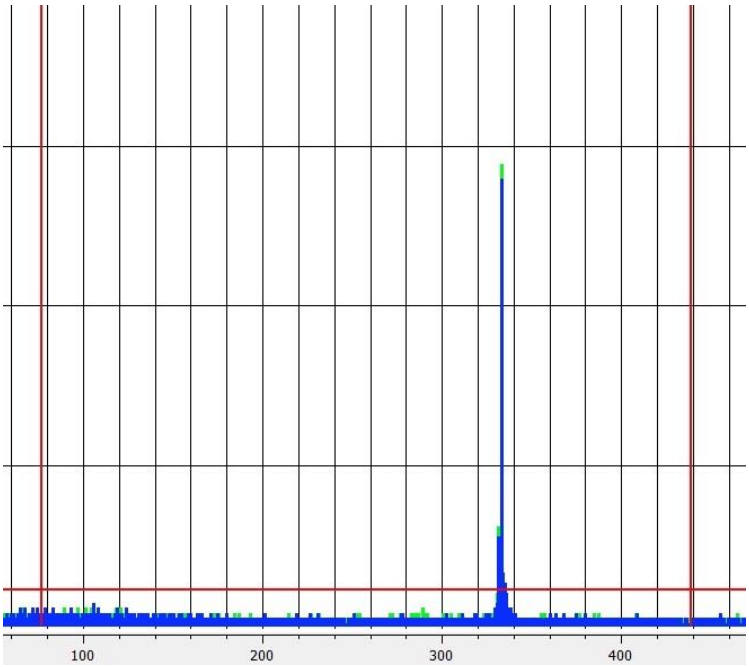

Fig. 22. Example of peak reflection from corner reflector, located at distance of 0.2 mile (330 m)

- Check that the target observed on the screen is really corners reflector. Contact a technician at point of corner reflector to shielding the reflector by a piece of carton. In that case, reflected signal level should fall significantly.

- Using alignment nuts/bolts at Fig. 20, run slow antenna beam mechanical scanning in both directions relative to the current direction in the azimuthal plane and fix the position corresponding to the highest level of the reflected signal.
- Repeat such scanning in elevation plane and fix the position corresponding to the highest level of the reflected signal. At this point the fine alignment of antenna is completed.
- Tight all the nuts, internal and external bolts of the adjustment mechanism. Remove the corner reflector from railway track.

5.2 Commissioning of Radar

- Close radarcapture2016.exe application at laptop. Disconnect radar data cable from laptop and connect it to stationary LAN/WAN to get radar connected to Data Center.
- Install radarcapture2016.exe or your proprietary software on Data Center to use radar as remote speed/distance sensor for safe train arrival to deadlock end of the track.

Congratulations! Since now, SDM-76 radar is commissioned to work online.

Note. Signal from SDM-76 radar can also be used within railway computerized safety system for automatic emergency braking of the train or loco when it approaches deadlock end with an unsafe high speed.

6 RADAR MAINTENANCE

Routine maintenance of SDM-76 radar is not required.

Ad hoc maintenance is carried out in the case of liquidation of consequences of adverse weather conditions (strong wind, snow), technical malfunction or other factors.

Stand behind or from side of radar antenna when cleaning it. Otherwise switch the power OFF or to STAND BY mode by radar software application.

Run maintenance in the following order:

- Inspect the radar, remove the dust, dirt, ice or snow from external surfaces, ensure there is no damage of external surfaces.
- Check the mount fixing to the support leg.
- Check the integrity of the ground and corrugated hose with data cable and power cable. Ensure a reliable cross-connection data and power cables with stationary cabling system.
- In the case of radar malfunctioning, check DC voltage in outdoor cross-box nearby the radar.
- Re-align the radar if necessary.

In the case of continuous radar malfunctioning, contact your Supplier or ELVA-1 to return the product to the factory for repair.

Attention! For the product subjected to unauthorized repair by the Customer, the manufacturer's warranty does not apply, and the repair is carried out by the Customer’s sole expensive.