Non-contact hydrological measurements

APPLICATION OF RADAR TECHNOLOGY FOR OPEN CHANNEL FLOW MONITORING

ADVANTAGES

- High measurement precision of surface velocity due to advanced radar technology
- Fast installation above the surface, no complex construction works, or flow shutdown required
- 24/7 real-time monitoring
- Low power consumption
- Low maintenance, no routine cleaning or inspection needed
- Measurements are not affected by sediments, mud or driftwood
- Ideal for hydrological, industrial and wastewater applications
- Robust sensors in IP68-rated enclosure, which normally operate above the water surface, provide stable and reliable measurements

MEASURING PRINCIPLE

Geolux hydrological instruments for contactless surface velocity measurement in open channels use radar technology to provide measurements. Application of radar technology results in high precision of measurements that are not affected by outside factors such as temperature, humidity or water density. Geolux instruments are well suited for surface velocity measurement of all types of rivers, streams, canals and both clean-water and waste-water channels.

Surface velocity is measured by transmitting radio waves towards water surface at an angle. The surface in an open channel is never perfectly flat, and even miniature waves that are present on the surface reflect radar waves back to the sensor. If the surface is moving, the frequency of the reflected radio waves is altered due to Doppler effect, and advanced receiver in surface velocity radar is able to measure even small changes in the frequency. The frequency difference is then converted automatically to surface velocity. The sensor also detects if the water is flowing towards or away from the sensor.

The same principle is used in police radar guns that detect speeding vehicles; however, greater accuracy and sensitivity are required for hydrological applications.

Low power consumption of RSS-2-300W surface velocity radar makes it suitable for real-time, continuous monitoring of water surface velocity.

One or more RSS-2-300W surface velocity radars can be combined together with water level meter to build a system that calculates total water discharge at a monitoring site with high accuracy.

To achieve optimal results, some care must be taken when selection installation site. Also, it is important that the instruments are installed properly. This document describes how to select a good installation site, and how to setup the instruments on the site.

Geolux

Geolux hydrology sensors based on state-of-the-art radar technology manufactured in EU provide reliable and accurate measurements.

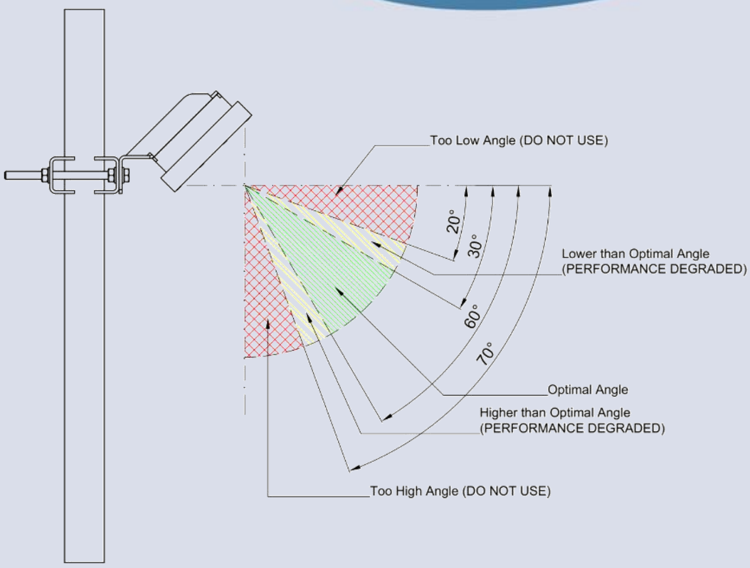
INSTALLATION & MAINTENANCE

The surface velocity radar is typically mounted on existing bridge or other existing channel superstructures. There is no requirement for special construction works or flow shutdown. Typical time required for full installation of an instrument is less than 1 hour. The instrument can also be used inside sewer channels with ceiling, provided that it is attached to the ceiling. Minimal required distance from the surface to the sensor can be as low as only 2 cm, and maximum up to 50m. It is also possible to mount the instrument on the side of the channel instead of mounting it above the channel. In this case it is required to manually calculate surface velocity compensation as the instrument heading angle is not parallel to the flow direction angle. Also, if the instrument is mounted on the side of the channel, the accuracy of measurements will be reduced.

The instrument operates without any contact with the water. This results in low-maintenance operation which is not affected by sediments, water contamination, driftwood or debris in the water. No routine inspection and cleaning of the instrument is required. Furthermore, it makes this type of sensor ideal for monitoring surface velocity of non-clean water, such as sewer and waste water channels. Sensor construction is made of highly mechanically and corrosion resistible anodized aluminium aviation grade 6061 alloy, front panel is manufactured from high quality Teflon and all screws are stainless steel A4 quality. As construction is made and certified IP68 there is no danger to the sensor if sensor is placed below maximum possible flooding level as even if submerged for longer period, there is no danger for the instrument damage during high water and flooding conditions.

ANGLE & FLOW DIRECTION

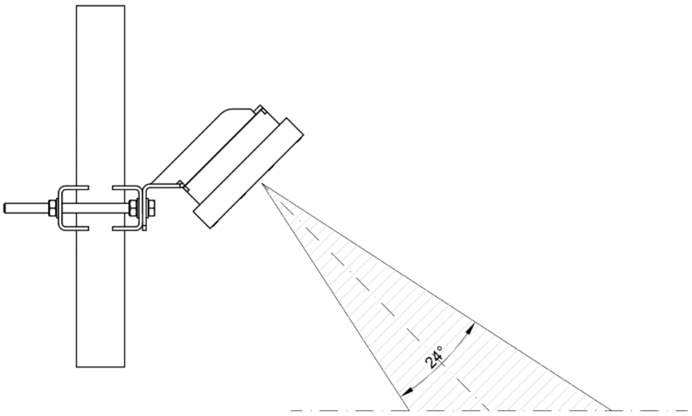
To achieve the specified accuracy, it is important to properly select measurement site and to install sensor with proper horizontal and vertical tilt angle. The tilt angle to horizontal plane should be between 30° and 60°, and it is recommended that the tilt angle does not exceed 45°. The instrument should be oriented in parallel with the water flow direction. For optimal operation, and best results, the instrument should be pointed upstream, so that the water flows towards the instrument.

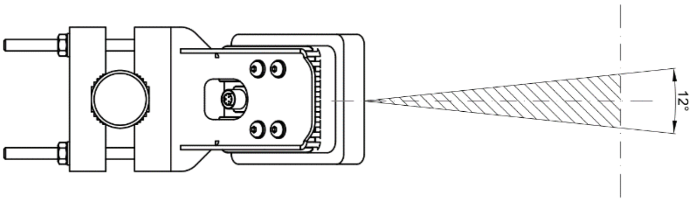


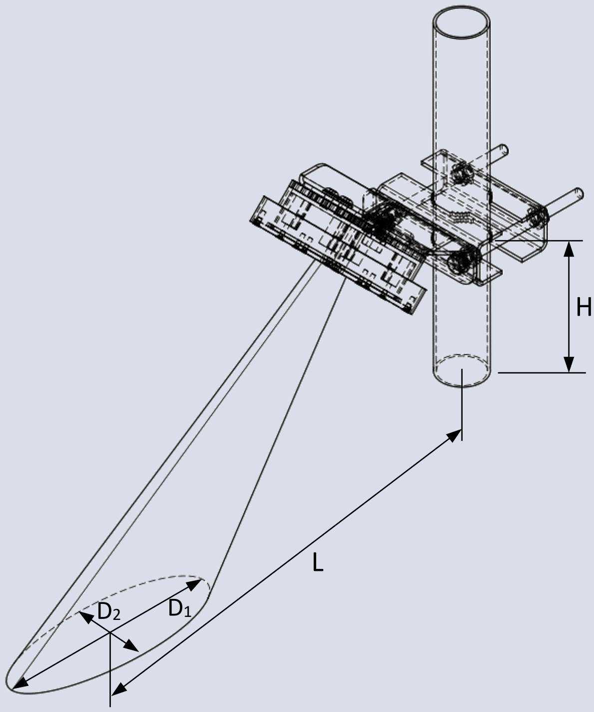
The instrument is equipped with internal inclination angle sensor. The measured inclination (tilt angle) is reported by the instrument and can be seen in the PC application for instrument configuration. It is strongly recommended to check the inclination measured by the instrument itself during equipment installation. This measurement is also used internally for automatic velocity cosine compensation.

The height of the instrument above the water surface and the inclination determine area on the surface that is covered by the radar beam. This measurement area should be clear of any obstacles. The structure holding the instrument (pole, bridge fence, etc.) must be solid and without vibrations. There should be no vegetation between the radar and the measurement area because it could affect measurement accuracy.

Radar beam will cover an elliptical area on the water surface. The radar reports average surface velocity of the covered area. Geolux RSS-2-300W instrument uses complex Kalman filters with physical modelling of the water flow to give stable measurements even under turbulent conditions. However, if the water flow is turbulent, fluctuations in measured data could be expected as well as somewhat reduced measurement accuracy. If turbulent flow can be expected at monitoring site, then the filter length of the radar should be configured to 120 or more.







The water flow at the installation site should be as uniform as possible. Reliable measurements will be obtained if the river channel is straight for at least 100 meters before the site, without curves and changes in the channel width. The water should be free from any turbulences such as vortexes, and should be at least 100 meters away from weirs or waterfalls.

Radar beam coverage area depends on the height of radar instrument above the water surface and instrument inclination (tilt angle). It can be approximated by an ellipse.

Calculated values for most common applications are shown in the table:

Angle →	30°			45°			60°		
Height [H]	L [m]	D_1 [m]	D_2 [m]	L [m]	D_1 [m]	D_2 [m]	L [m]	D_1 [m]	D_2 [m]
1m	1.7	2.0	0.4	1.0	0.9	0.3	0.6	0.6	0.2
2m	3.5	3.9	0.8	2.0	1.8	0.6	1.2	1.2	0.5
3m	5.2	5.9	1.3	3.0	2.7	0.9	1.7	1.7	0.7
4m	6.9	7.9	1.7	4.0	3.6	1.2	2.3	2.3	1.0
5m	8.7	9.8	2.1	5.0	4.5	1.5	2.9	2.9	1.2
6m	10.4	11.8	2.5	6.0	5.3	1.8	3.5	3.5	1.5
7m	12.1	13.8	2.9	7.0	6.2	2.1	4.0	4.0	1.7
8m	13.9	15.7	3.4	8.0	7.1	2.4	4.6	4.6	1.9
9m	15.6	17.7	3.8	9.0	8.0	2.7	5.2	5.2	2.2
10m	17.3	19.7	4.2	10.0	8.9	3.0	5.8	5.8	2.4

For more information, please visit our web page:

www.geolux-radars.com/hydrology or contact us at: geolux@geolux.hr

Uniformity of water flow is most important factor for obtaining accurate and stable measurements. Turbulences should be avoided. By adjusting the radar inclination angle and instrument position, it is possible to select the optimal area on the water surface from which the measurements will be taken.

It is important to understand that the water is very reflective medium for radio waves. When the radar beam hits water surface, most of the energy of radar beam will be reflected away, and only a small portion of radar beam energy that hits waves on the water surface will be reflected back to the radar sensor. This reflected part of radar beam, going back to the radar is used to measure surface velocity. The amount of energy reflected back to the radar sensor depends on the roughness of the water surface. For radar to operate properly, it is required that there are small waves present on the water surface. Geolux RSS-2-300W requires minimal wave height of 1 mm for proper operation, which is less that what many of our competitors require as RSS-2-300W uses very sensitive receiving elements in the radar sensor.

The benefit of using high sensitivity receivers is the ability to measure low velocities with minimal surface roughness. The downside is that the radar is susceptible to multipath effects that can happen on some specific sites when a part of the radar beam hits the water surface, reflects from the water surface away to another object such as nearby bridge, and is then reflected from the secondary object back to the radar sensor. On majority of installation sites, the multipath effect is non-existent.

RAIN & WIND

Geolux RSS-2-300W radars have integrated internal software filters to filter out effects of rain, fog or wind. These filters however have some limitations. Majority of measurement inaccuracies caused by environmental factors can be solved by proper sensor installation.

For rain suppression, the most effective solution is to mount the radar so that it points upstream and the water flows towards the radar. As rain falls down and the radar is tilted downwards, rain droplets will move away from the radar, while the water flows towards the radar. The radar can then easily distinguish the water movement from rain movement. To further improve rain filtering, the radar should be configured to report only incoming direction of water flow. In this case, the radar will completely ignore all movement with direction going away from the sensor. Of course, on some sites it is possible that the water will flow in both directions, so for such sites, the radar sensor should be configured to report both incoming and outgoing flow, by selecting "both direction" setting in the radar sensor.

Additional rain suppression can be implemented by mounting the radar below some structure so that the first 1 to 2 meters in front of the radar are free of rain. As the energy of the radar beam drops exponentially with distance, radar is most sensitive to the rain directly in front of the radar. If the radar instrument is being mounted on a bridge, whenever possible, it should be mounted below the bridge instead of on the side of the bridge, so that the bridge provides cover from the rain directly in front of the instrument.

Influence of the wind on the accuracy of measured data is, in most cases small and can be neglected. The only exception is strong wind as it will create surface waves that are traveling in different direction from the water flow.

MEASUREMENT QUALITY INDICATOR

Geolux RSS-2-300W radar is constantly calculating various parameters of the signal in the signal processing algorithms and will continuously with measurement data report also measurement quality. Quality indicator value is in range from 0 (the best quality) to 3 (the worst quality) and can be used to interpret data in the analysis software with better understanding and confidence.

For example, when radar is mounted on the railway bridge, one of common applications, measurements will be very good quality most of the time except when train is passing the bridge due to the extensive vibrations. In this case radar will still report measurements but values could be quite wrong, but also measurement quality indicator value will go up to the higher value. It is up to every user to interpret quality indicator value for their application, but general recommendation is that measurements with quality indicator 3 cannot be trusted, value 2 could be questionable and values 1 and 0 are very good and accurate.

SIGNAL STRENGTH

Good signal-to-noise ratio (SNR) is the most important parameter of the radar signal that provides accurate and stable surface velocity measurements. When more radar energy is reflected back from the water surface to the radar sensor, the overall signal strength is higher. When less energy is reflected back, as it is when the water surface roughness is lower, the signal strength is lower. If the amount of noise present in the signal remains the same, when the surface roughness is lower, SNR will drop. To improve SNR internally, the radar uses low-noise programmable gain amplifier (PGA). If the strength of reflected signal is ow, the radar will increase gain level on PGA. If the strength of reflected signal is higher, gain level will be automatically reduced.

The best indication of good signal strength is PGA value in the radar status report messages. This value is automatically changed with AGC (automatic gain control) algorithm in the radar. Minimal possible gain is 1 and maximal possible gain is 200. Beast measurement results are obtained when PGA gain level is between 5 and 100; if PGA gain is lower than 5, this means that the reflected signal is very strong and it can oversaturate the receiver, which could result in reduced accuracy. Gain 200 should be avoided as it is usually indication of very low reflections from the water surface.

INTERFERENCE & MULTIPLE RADARS

The radar operates in K band, in frequency range around 24.125 GHz. Frequency stability and phase noise of the internal oscillator is very good and always trimmed in factory to precise central frequency but even with the best possible trimming and most stable oscillators it is very unlikely that two devices will be working on the exact same frequency to cause interference. Doppler frequency shift caused by water in speed range up to 15m/s is measured in kHz frequency shift. As this frequency shift is relatively small in comparison to the central frequency, in most cases below 0,00005%, it will be required to keep difference between central frequencies of two radars in the same range to get interference. Such central frequency precision is impossible with currently available commercial grade components and in most cases even the best differences will be measured in MHz offset from central frequency.

Similarly, as interference from two or more RSS-2-300W radars on the same location it is very unlikely that other radiation sources in K band will affect radar measurements also. It is possible that some wideband radiation sources can introduce small and impulse interference for the short period of time, but this should not, or it is very unlikely to affect measurements reported by radar sensor.

LOW POWER & BATTERY

Low power consumption and wide power supply voltage range of the units enables battery-powered operation on remote sites where electric grid power supply is not available. Sensors are also designed to be regularly powered-off and powered-on to save power. In power-off and power-on mode of operation recommended minimal period to keep instrument working before taking the measurements is around 20s to 40s mostly depending on the location and turbulences on the water surface. This minimal time period will allow sensor to tune programable gain, filters, tracking algorithms and all other internal adaptive systems for best SNR and best measurement accuracy.

When combined with Geolux datalogger which completely powers-off sensors between periodic measurements, the senor can be operating on battery power, even without solar panel, for over one year.

RSS-2-300W SPECIFICATION

GENERAL

Radar Type	K-band 24.125GHz/24.200GHz Doppler radar, 27 dBm EIRP
Beam Angle	12° Azimuth, 24° Elevation
Detection Distance	50m
Speed Range	0,02 m/s to 15 m/s
Resolution	0,001 m/s (*1 mm/s)*
Accuracy	1%
IP Rating	IP 68

INTERFACE

Serial Interface	1 x serial RS-485 half-duplex 1 x serial RS-232 (two wire interface)
Serial Baud Rate	1200 bps to 115200 bps
Serial Protocols	ASCII-S, GLX-NMEA, Modbus
CAN Interface	Up to 1Mbps CAN2.0
Alarm Outputs	2 x open collector, max 50V 200mA
Connector	M12 circular 12pin

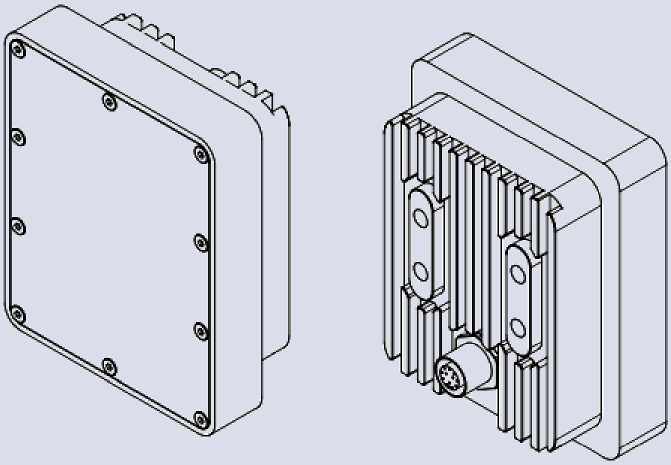
ELECTRICAL & MECHANICAL

Power Input	9 to 27 VDC
Power Consumption	< 1,35W (typical 1,0W)
Maximal Current	< 250 mA
Temperature Range	-40°C to +85°C (without heating or coolers)
Enclosure Dimensions	110 mm x 90 mm x 50 mm

FCC & CE APPROVED

EN 6095-1:2006
EN 62311:2008
EN 301 489-3, EN 301 489-1
EN 61000-6-3:2007
EN 61000-6-2:2007
EN 300 440:2017

FCC Part 15 Class B
FCC ID: 2AN9XRSS2300W



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