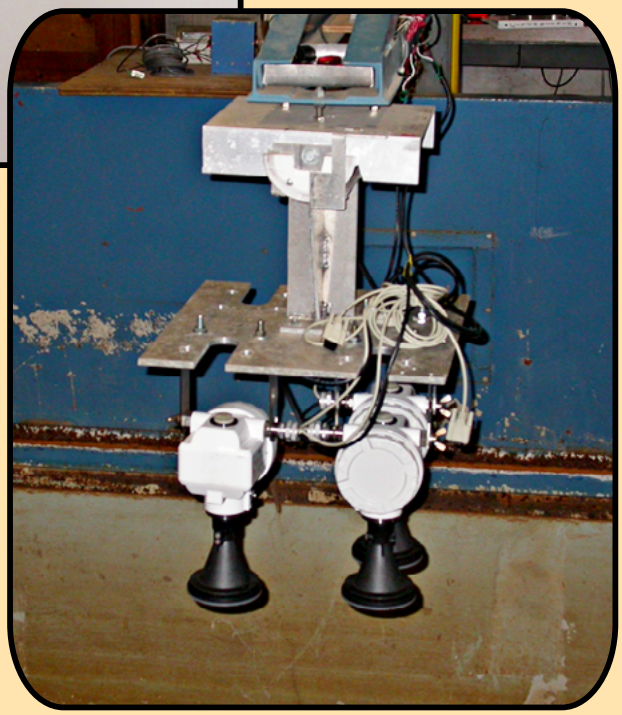
USGS
science for a changing world

Laboratory Evaluation of the Design Analysis Associates DAA H-3613i Radar Water-Level Sensor—Results of Temperature, Distance, and SDI-12 Tests



Open-File Report 2016–1124

U.S. Department of the Interior
U.S. Geological Survey

Cover Images. Photographs showing Design Analysis Associates DAA H-3613i radar water-level sensor display (see fig. 2, p. 2) and three Design Analysis Associates DAA H-3613i radar water-level sensors installed on positioning arm for distance-accuracy test conducted at the U.S. Geological Survey Hydrologic Instrumentation Facility's Hydraulic Laboratory (see fig. 6, p. 4).

Laboratory Evaluation of the Design Analysis Associates DAA H-3613i Radar Water-Level Sensor—Results of Temperature, Distance, and SDI-12 Tests

By Mark V. Carnley

Open-File Report 2016–1124

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Director

U.S. Geological Survey, Reston, Virginia: 2016

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment—visit http://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit http://www.usgs.gov/pubprod/.

Suggested citation: Carnley, M.V., 2016, Laboratory evaluation of the Design Analysis Associates DAA H-3613i radar water-level sensor—Results of temperature, distance, and SDI-12 tests: U.S. Geological Survey Open-File Report 2016–1124, 7 p., http://dx.doi.org/10.3133/ofr20161124.

ISSN 2331-1258 (online)

Contents

Figures

Tables

Laboratory Evaluation of the Design Analysis Associates DAA H-3613i Radar Water-Level Sensor—Results of Temperature, Distance, and SDI-12 Tests

By Mark V. Carnley

Abstract

The Design Analysis Associates (DAA) DAA H-3613i radar water-level sensor (DAA H-3613i), manufactured by Xylem Incorporated, was evaluated by the U.S. Geological Survey (USGS) Hydrologic Instrumentation Facility (HIF) for conformance to manufacturer's accuracy specifications for measuring a distance throughout the sensor's operating temperature range, for measuring distances from 3 to 15 feet at ambient temperatures, and for compliance with the SDI-12 serial-to-digital interface at 1200-baud communication standard. The DAA H-3613i is a noncontact water-level sensor that uses pulsed radar to measure the distance between the radar and the water surface from 0.75 to 131 feet over a temperature range of −40 to 60 degrees Celsius (°C). Manufacturer accuracy specifications that were evaluated, the test procedures that followed, and the results obtained are described in this report. The sensor's accuracy specification of ± 0.01 feet (± 3 millimeters) meets USGS requirements for a primary water-stage sensor used in the operation of a streamgage. The sensor met the manufacturer's stated accuracy specifications for water-level measurements during temperature testing at a distance of 8 feet from the target over its temperature-compensated operating range of −40 to 60 °C, except at 60 °C. At 60 °C, about half the measurements exceeded the manufacturer's accuracy specification by not more than 0.005 feet. The sensor met the manufacturer's stated accuracy specifications for water-level measurements during distance-accuracy testing at the tested distances from 3 to 15 feet above the water surface at the HIF.

Introduction

The U.S. Geological Survey (USGS) Hydrologic Instrumentation Facility (HIF) evaluates the performance of instruments and equipment used to directly measure hydrologic data. USGS accuracy requirements are routinely examined and reported when instruments are evaluated at the HIF. These devices may measure parameters needed to quantify streamflow (such as river stage, water velocity, or water discharge) to monitor groundwater levels or to measure water-quality parameters in a variety of field settings. In addition, the HIF evaluates the performance of instruments and equipment that are used in combination with other devices that directly measure hydrologic data. These devices include data loggers and recorders, radios for data telemetry, power supplies, solar panels, batteries, cableway- and bridge-measuring equipment, and water-quality sampling devices. The performance of these devices is evaluated in a variety of ways; however, the primary factors evaluated are:

- the manufacturer's stated specifications for accuracy and resolution;
- any relevant USGS accuracy requirements;
- the ability of the device to operate under a wide range of environmental conditions at remote, unmanned field stations;
- power source and power consumption; and
- compatibility with existing USGS field hydrologic data-collection infrastructure and equipment.

The evaluations may involve extended operation in one or more field locations and (or) may employ testing chambers designed to reproduce a range of environmental conditions. Instrument equipment evaluations are done primarily to determine particular devices suitable for use by USGS personnel for hydrologic data collection.

This report describes the procedures followed and the results obtained from the testing of a commercially available water-level measuring device, the Design Analysis Associates DAA radar water-level sensor (DAA H-3613i). Test results are for the version of the model available at the time of testing and do not reflect any future improvements made by the manufacturer.

Description of the Design Analysis Associates DAA H-3613i Radar Water-Level Sensor

The Design Analysis Associates DAA radar water-level sensor (DAA H-3613i) is a small, lightweight radar unit manufactured by Xylem, used for measuring water levels in surface-water applications. The DAA H-3613i (fig. 1) has no direct contact with the water surface and is not susceptible to damage by ice, logs, debris, sediment, or aquatic fouling. The sensor has a sealed antenna. It has two 6-foot (ft) communication cables: one for Serial Data Interface at 1200 baud (SDI-12) and one for serial (RS-232) communications. The sensor is approved by the Federal Communications Commission and the USGS Radio Officer.

The DAA H-3613i measures water level by emitting short bursts of radio wave energy through an antenna and by measuring the transit time of the signal reflected from the water surface. Distance from the radar to the water surface is calculated using the following equation: $(Distance = c[\frac{TransitTime}{2}])$, where c is a constant representing the speed of 1ight. The DAA H-3613i makes multiple distance measurements, averages the results, and converts the distance into stage in units of feet, meters, or other units, based on the user's selected configuration.

The sealed antenna has a condensation/water drip point located directly in the center of the antenna. This eliminates measurement problems from condensation and keeps insects from building nests or webs inside the antenna. For a detailed explanation of noncontact measurements and sensors, see U.S. Geological Survey Techniques and Methods book 3, chapter A7, p. 26–27, at http://pubs.usgs.gov/tm//tm3-a7/.

The sensor has a built-in liquid crystal display that displays the distance from the water surface to the radar's sensor reference point. The display has three buttons that are used to display readings and to monitor and edit the radar sensor configuration (fig. 2). The display is viewed by removing the display housing cover. The display tethered to the radar can be detached for handheld use. The DAA H-3613i has a built-in SDI-12 interface that provides power and communications with a SDI-12-compatible data logger. The radar can be configured using ToF Tool—the manufacturer's software—and a serial cable.

ToF Tool (fig. 3) is a powerful Windows-based sensor configuration and diagnostic program that is available upon request from Design Analysis Associates. The program is not usually needed to install the radar, but can be very useful for locations where the radar cannot be installed without interference from structural surfaces, such as beams, brackets, and side walls. ToF Tool is used to map the radar-beam profile and to optimize the profile by means of electronic suppression of interference echoes.

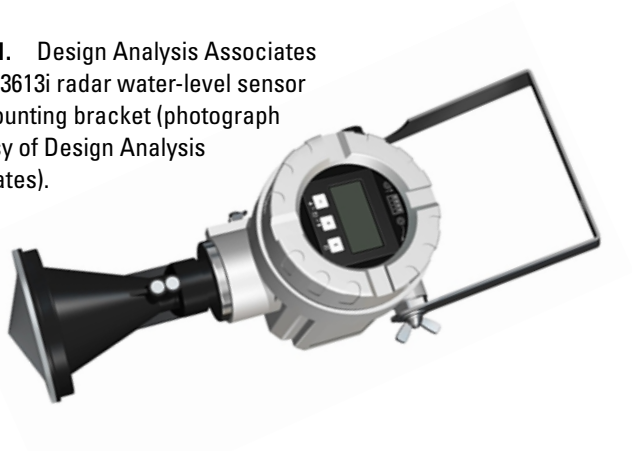


Figure 1. Design Analysis Associates DAA H-3613i radar water-level sensor with mounting bracket (photograph courtesy of Design Analysis Associates).

Figure 2. Design Analysis Associates DAA H-3613i radar water-level sensor display.

Figure 3. Design Analysis Associates DAA H-3613i radar water-level sensor configuration and diagnostic program—ToF Tool Fieldtool Package (photograph courtesy of Endress + Hauser).

The DAA H-3613i is warranted for 2 years against material defects and performance from date of shipment. Selected manufacturer's specifications for this sensor are listed in table 1 and are available at http://www.waterlog.com/productsdetail.php?Radar-Series-H-3611-12-13-2 (*waterlog.com March 2015*).

Methods

Three DAA H-3613i's were tested: serial numbers 1016, 1017, and 1018. The DAA H-3613i's were tested in the HIF's walk-in temperature chamber to confirm manufacturer temperature compensation specifications. The sensor's distance-to-water (air gap) measurement accuracy was checked against the manufacturer's specification at the HIF Hydraulic Laboratory over a static pool of water using a custom manually operated vertical-positioning system. SDI-12 compliance was tested using a commercially available SDI-12 Verifier (NR Systems SDI-12 Verifier).

Temperature Test

Temperature testing consisted of mounting the three DAA H-3613i's on a jig inside a large walk-in environmental chamber and horizontally pointing the radars toward a flat aluminum target located approximately 8 ft away (fig. 4). The radars were set to read an arbitrary stage of 10.00 ft for the target distance of 8 ft. The initial radar measurement at room temperature was used as the reference measurement for that radar. The difference between a measurement and the initial measurement was used to determine if the radar measured within accuracy specifications over the operating temperature range. The Design Analysis Associates DAA H-377 (DAA H-377) analog temperature sensor was used to record air temperature inside the chamber.

Table 1. Manufacturer specifications for the Design Analysis Associates DAA H-3613i radar water-level sensor.

[IP65, aluminum powder coating; lbs, pounds; SDI, serial data interface; VDC, volts direct current; ~, approximately; GHz, gigahertz; ft, feet; ms, millisecond; s, second; ◦C, degrees Celsius]

Feature	Specification
Housing dimensions	6.0 x 6.0 x 13.0 inches
Housing material	Aluminum-coated IP65
Weight	7.0 lbs
Communication interface	SDI-12, RS-232 for diagnostic only
Power supply	10 to 16 VDC
Current consumption	Measurement and standby (8 mA) Startup (20 mA)
Frequency	~26 GHz
Beam angle	±10 degrees
Beam diameter at 30 ft	2.62 ft
Measurement time	800 ms (typical) 5 sec (maximum)
Range	0.75 to 131 ft
Accuracy	±0.01 ft
Resolution (SDI-12)	0.001 ft
Compensated temperature range	−40 to 60 ◦C
Storage temperature range	−40 to 80 ◦C

Figure 4. Design Analysis Associates DAA H-3613i radar water-level sensor (serial number 1016) environmental chamber testing configuration.

The DAA H-377 has a measurement range of −40 to 60 ◦C with a measurement accuracy of ±0.2 ◦C. Sensor-stage measurements and inside walk-in-chamber air-temperature data were recorded using a Design Analysis Associates DAA H-500 data logger and sampled at 5-minute intervals. The three sensors were connected to the logger using SDI-12. Temperatures varied over the operating range of the radar, from −40 to 60 ◦C, by manually setting the temperature chamber controller for the following set temperatures: −40, −20, 0, 25, 40, and 60 ◦C (fig. 5). The solid green line in the figure denote the temperatures applied during testing. The radars were kept at set temperatures for at least 3 hours. During temperature testing, the temperature varied from −30 to −40 ◦C because of the mechanical limitations of the environmental chamber. The radar was kept at −40 ◦C for at least 6 hours during this phase. This is sufficient time to evaluate the radar's performance.

Distance Accuracy Test

The accuracy of the DAA H-3613i distance-to-water-surface measurement was evaluated by using a custom vertical positioning system. The radars were mounted on a positioning arm located over the water-filled sump at the exit of a large tilting flume (fig. 6) in the HIF Hydraulics Laboratory. The static water level in the sump was measured with a reference

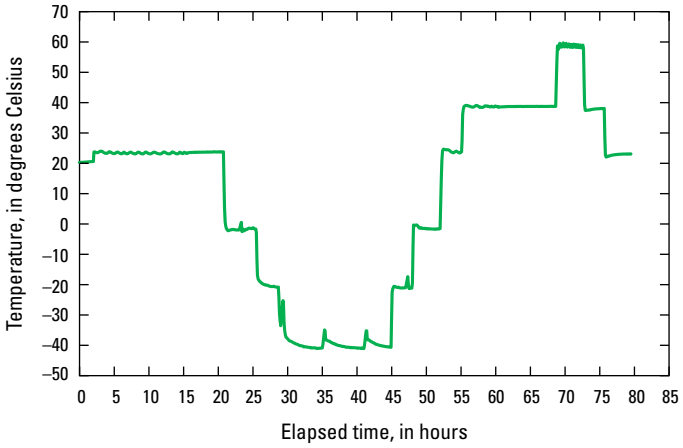


Figure 5. Temperatures measured during static-target temperature testing at set temperatures of –40, –20, 0, 25, 40, and 60 degrees Celsius for the three Design Analysis Associates DAA H-3613i radar water-level sensors.

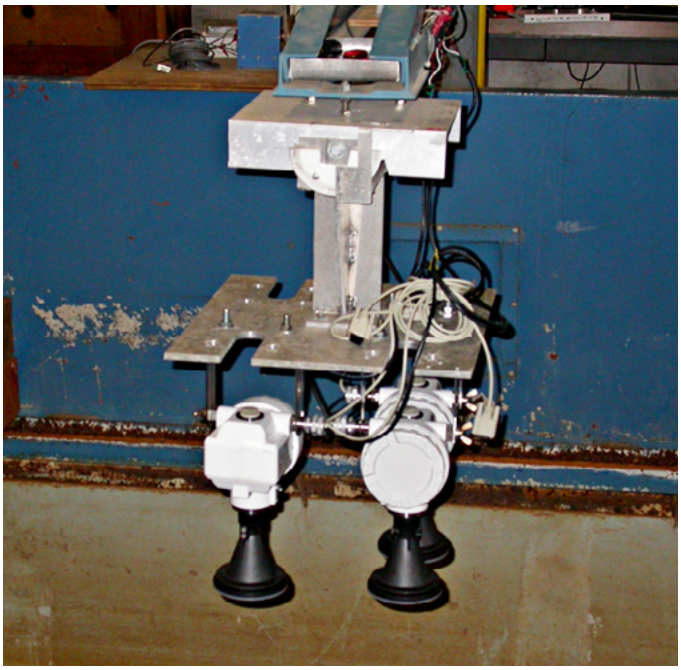


Figure 6. Three Design Analysis Associates DAA H-3613i radar water-level sensors installed on positioning arm for distance-accuracy test conducted at the U.S. Geological Survey Hydrologic Instrumentation Facility's Hydraulic Laboratory.

instrument float encoder and the location of the vertical positioning arm was measured with a reference instrument encoder attached to the positioning arm. A Design Analysis Associates DAA H-350XL data logger connected to the instruments with SDI-12 was used to sample and log measurements made by the radars and the encoders every 3 minutes. Water-level readings were manually logged from the encoder and compared to the measurements recorded by the data logger at every reposition of the arm. The vertical arm position was controlled manually with a motor controller and has a maximum range of 15 ft above the water. The accuracy specification was evaluated by comparing the changes in the distance to water surface (air gap) measured by the radar, with the changes in distance to water surface; the air gap was measured by the reference instruments, the arm position, and water-level encoders). The change in air gap was determined from the initial measurement made at the highest arm position.

Five distance-to-water-surface tests were conducted by varying the distances to the water surface in 3-ft increments. For each test, the arm and radars were positioned at the maximum air gap (15.00 ft), then moved in 3-ft increments down to the minimum tested air gap (3.00 ft), and then moved up to the maximum air gap (15.00 ft). The range of the test setup limited the distance-to-water surface tests to a small portion of the measurement range of the radars.

SDI-12 Testing

SDI-12 testing was performed to check the DAA H-3613i for compliance with the SDI-12 version 1.3 (SDI-12 Support Group, 2013). The NR Systems SDI-12 Verifier (Verifier) with firmware version 2.2 and personal computer (PC) software version 6.0 was used for the test. The Verifier is a PC-based system that verifies the compliance of SDI-12 sensors and loggers with the communication timing and command set of the SDI-12 standard. The DAA H-3613i is compliant with the SDI-12, version 1.3, based on verification testing by the HIF. No testing was performed to confirm the SDI-12 electrical specification.

Results

The DAA H-3613i test results from the temperature and distance accuracy tests were compared to the USGS Office of Surface Water (OSW) accuracy requirements. The USGS OSW accuracy requirement for stage-measuring instruments is "the larger of 0.01 ft or 0.20 percent of reading" with an implied measurement resolution of 0.01 ft.

Temperature Test

Three DAA H-3613i's were evaluated at varying temperatures over a fixed distance using the methods previously described. Results from temperature testing are plotted in figures 7, 8, and 9. Red dotted lines in the figures denote the USGS OSW accuracy requirement set forth in OSW Technical Memo 96.05 (http://water.usgs.gov/admin/memo/SW/sw96.05.html). Total test time in the walk-in chamber was 80 hours. Except at the highest test temperature, the measurements were within manufacturer's accuracy. At the highest temperature, about half of the differences with the reference were slightly outside of the manufacturer's accuracy by less than 0.005 ft.

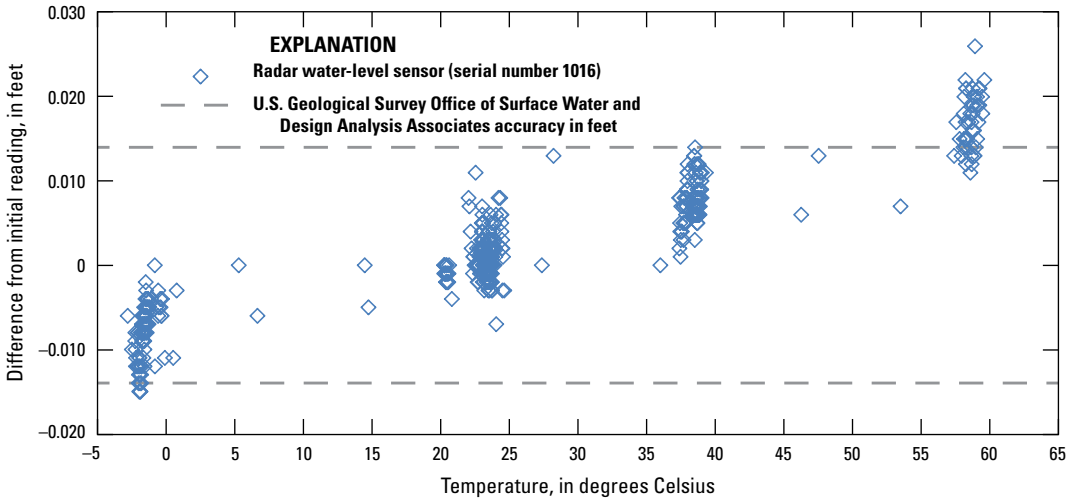


Figure 7. Differences from initial reading in feet during temperature testing for Design Analysis Associates DAA H-3613i radar water-level sensor (serial number 1016) for six temperatures.

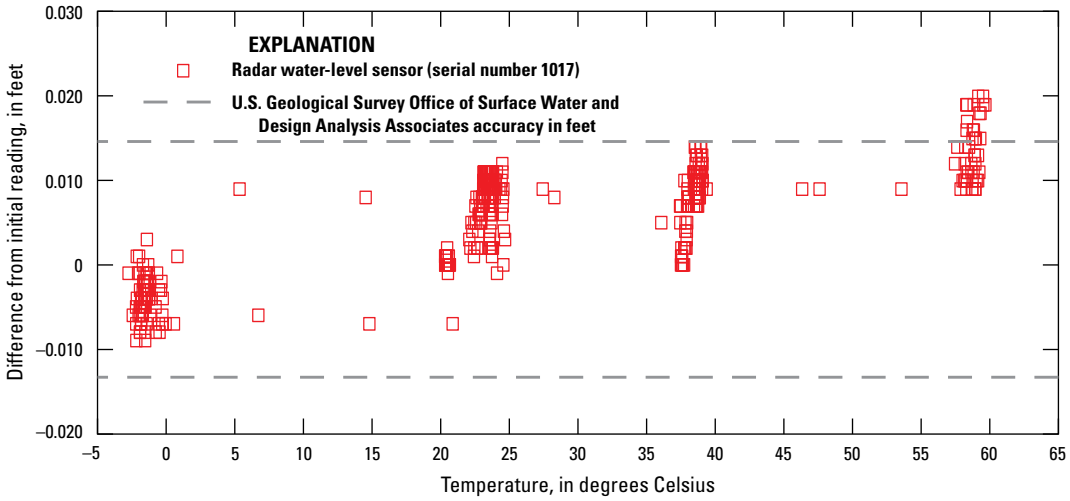


Figure 8. Differences from initial reading in feet during temperature testing for Design Analysis Associates DAA H-3613i radar water-level sensor (serial number 1017) for six temperatures.

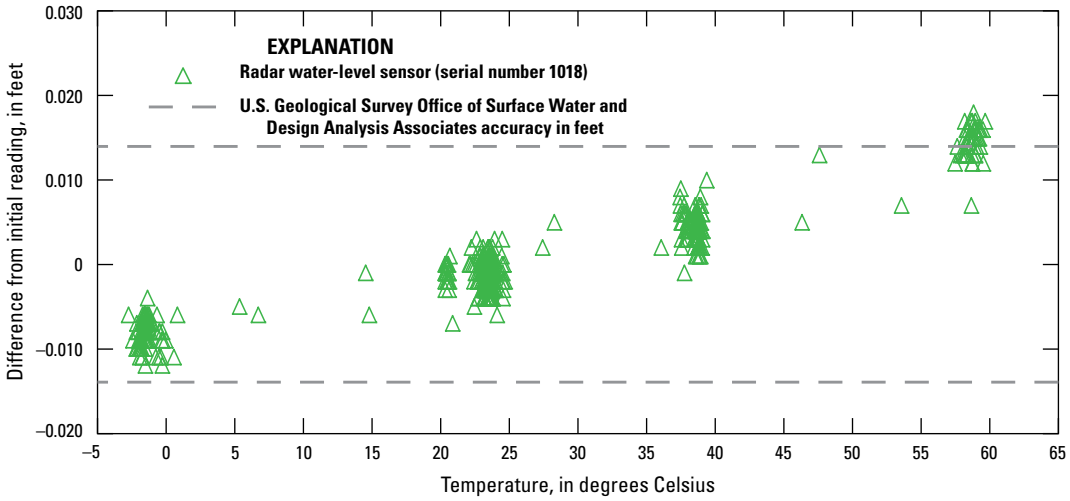


Figure 9. Differences from initial reading during temperature testing for Design Analysis Associates DAA H-3613i radar water-level sensor (serial number 1018) for six temperatures.

Summary statistics of the differences between each measurement and the initial measurement are located in table 2. The summary statistics were computed from the first 222 measurements made at each temperature so that each temperature would have the same contribution to the summary statistics. The sum of the average difference and standard deviation of the difference for the radars are within USGS OSW accuracy requirements and the manufacturer's accuracy specification.

Distance Accuracy Test

Distance accuracy tests were performed as previously described in the Methods section. The differences between the changes in air gap, measured by the radar and reference measurements, were used to evaluate compliance with air-gap accuracy specification over the 15-foot test range. Each test was performed while the sump water-level reading was static. The data from the five tests are plotted in figure 10. Each data point was considered to be within OSW accuracy requirements if the data point was on or between the accuracy limits. All data points were within the accuracy limits. Summary statistics for the distance accuracy test are located in table 3.

SDI-12 Testing

SDI-12 Verifier testing was performed on each DAA H-3613i water-level sensor for SDI-12 version 1.3 compliance. All responses returned from the three DAA H-3613i water-level sensors for SDI-12 version 1.3 using the NR Systems SDI-12 Verifier were correct and within the specified time constraints.

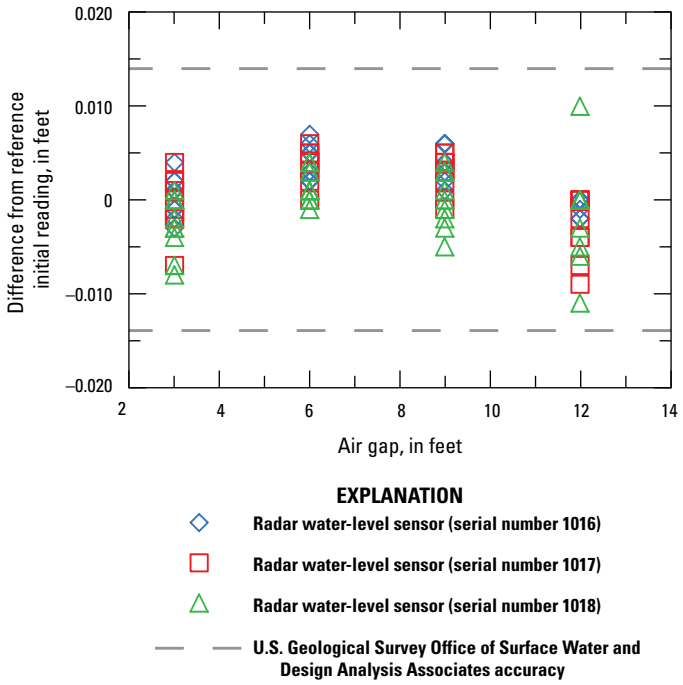


Figure 10. Differences between the changes in air gaps (distance to water) measured by the Design Analysis Associates DAA H3613i radar water-level sensor and measured by the references during positioning arm test conducted at the U.S. Geological Survey Hydrologic Instrument Facility's Hydraulic Laboratory. The references were the arm position and water level measured by a float system.

Table 2. Summary statistics for the difference between the distances measured at temperatures of –40, –20, 0, 25, 40, and 60 °C and the distance measured initially for three Design Analysis Associates DAA H-3613i radar water-level sensors.

Statistic	Serial number of evaluated device		
	1016	1017	1018
Number of measurements	222	222	222
Maximum difference in feet	0.026	0.020	0.018
Minimum difference in feet	−0.016	−0.013	−0.016
Average difference in feet	−0.001	0.002	−0.002
Standard deviation of difference in feet	0.012	0.010	0.010

Table 3. Summary statistics of differences between the change in air gaps (distance to water) measured by the Design Analysis Associates DAA H3613i radar water-level sensor and measured by the references during the positioning arm test conducted at the U.S. Geological Survey Hydrologic Instrumentation Facility's Hydraulic Laboratory. Air gaps varied from 3 to 15 ft.

Statistic	Serial number of evaluated device		
	1016	1017	1018
Number of measurements	40	40	40
Maximum in feet	0.009	0.007	0.010
Minimum in feet	−0.002	−0.009	−0.009
Average difference in feet	0.0003	0.002	0.000
Standard deviation in feet	0.003	0.004	0.003

Summary

Three Design Analysis Associates DAA H-3613i radar water-level sensors (DAA H-3613i's) with an operating measurement range of 0.75 to 131 ft of distance to water were evaluated to determine if they met the manufacturer's stated accuracy specifications and if they were suitable for use in U.S. Geological Survey (USGS) hydrologic data-collection activities. The tests involved subjecting the DAA H-3613i's to temperature testing from −40 to 60 °C. Except at 60 °C, the three DAA H-3613i's meet the manufacturer's stated accuracy specifications within the temperature-compensated operating range of −40 to 60 °C. At 60 °C about half the measurements exceeded the manufacturer's accuracy specification by not more than 0.005 feet. Distance-to-water-surface testing verified the radar's distance to water surface over a 15-ft distance to water surface. Based on the test results, the device is properly temperature compensated. The sensors evaluated meet the USGS requirements for accuracy of stage measurements at USGS continuous record streamflow-gaging stations over the range tested.

References Cited

Sauer,V.B., and Turnipseed, D.P. 2010, Stage measurement at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A7, p. 26−27, at http://pubs.usgs.gov/tm//tm3-a7//.

SDI-12 Support Group, 2013, SDI-12—A serial-digital interface standard for microprocessor-based sensors, version 1.3, 50 p., accessed January 22, 2016, at http://www.sdi-12.org/current%20specification/SDI-12_version1_3%20January%2026,%202013.pdf.

Yorke, T.H., 1996, Policy concerning accuracy of stage data: U.S. Geological Survey Office of Surface Water Technical Memorandum 96.05, accessed April 5, 2013, at http://water.usgs.gov/admin/memo/SW/sw96.05.html.

For more information, contact:
Hydrologic Instrumentation Facility
Building 2101
Stennis Space Center, MS 39529
http://water.usgs.gov/hif/

USGS Publishing Service Center staff:
Marilyn A. Billone, Editor
Ronald Spencer, layout

ISSN 2331-1258 (online)
http://dx.doi.org/10.3133/ofr20161124