FIELDSCOUT®

TDR 150
Soil Moisture Meter

PRODUCT MANUAL

Item # 6445

Spectrum®
Technologies, Inc.

General overview

Thank you for purchasing the Field Scout™ TDR 150 soil moisture, electrical conductivity and soil surface temperature meter. This manual describes the meter's general features and operation.

Soil moisture is a critical, and potentially highly variable, component of the soil environment. Time domain reflectometry is a proven technology for quickly and accurately determining volumetric water content (VWC) in soil. Electrical conductivity (EC) is a function of the moisture and salt in the soil. The meter also measures soil surface temperature. The user can quickly transition between taking VWC readings in standard and high-clay mode.

The meter's built-in data logger eliminates the need to record data manually. The data points can be viewed with the FieldScout Mobile app that maps out soil measurements using logged location coordinates (see p. 27). Measurements can also be saved to a USB drive that is plugged into the built-in USB port. The meter can be upgraded (item 6445GBU) to activate Bluetooth and GNSS.

Contents

Your shipment includes the following components:
- TDR 150 meter
- Carrying case
- 4 AA batteries

Note: **TDR rods are sold separately**

This manual will familiarize you with the features and operation of your new Field Scout™ TDR 150 Soil Moisture Meter. Please read this manual thoroughly before using your instrument.

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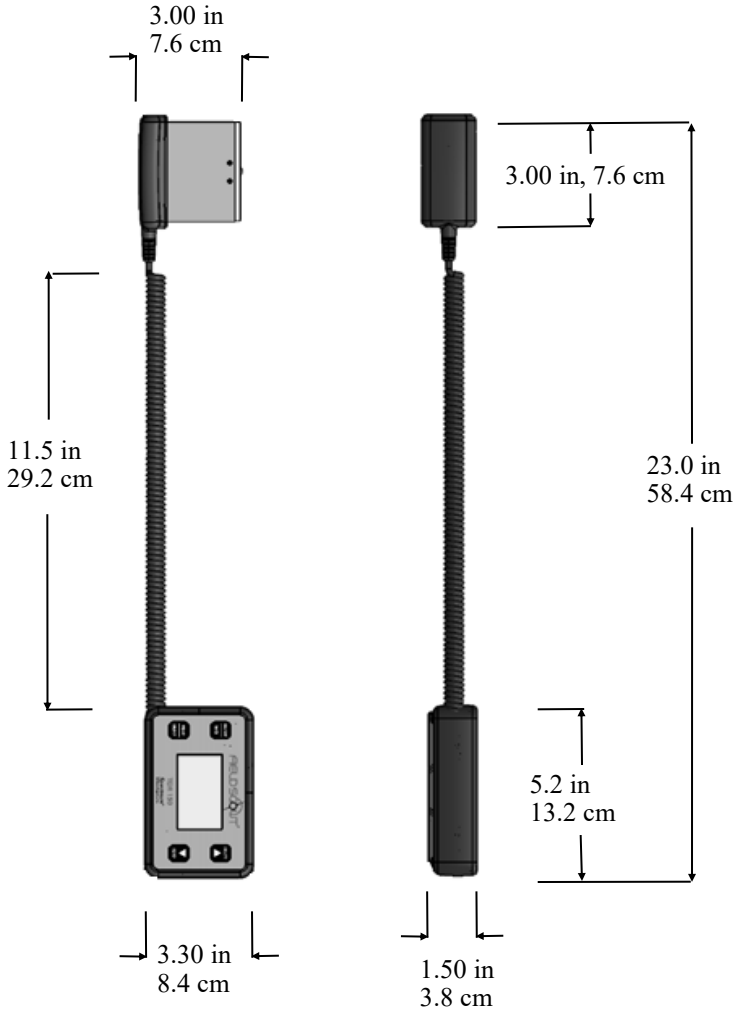
Specifications

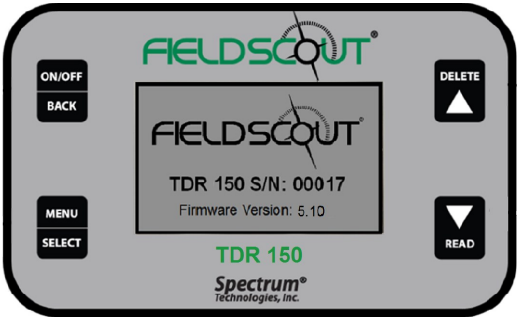
Measurement Units	Percent volumetric water content (VWC) Period (raw sensor reading)
Resolution, Accuracy and Range	**VWC**: 0.1% increment ±3.0% @ < 2 mS/cm 0% to Saturation (*Saturation is typically around 50% volumetric water*) **EC**: 0.01 increment ; ± 0.1 mS/cm; 0 - 5 range **Temperature**: 0.2 ˚F (0.1 ˚C) increment ; ± 1.8 ˚F (± 1 ˚C); -22 to 140 ˚F (-30 to 60 ˚C) Thermistor based; Infrared Optional
Connectivity	USB Type A, Bluetooth Low Energy*
GNSS*	Accuracy Galileo 1m; GPS 3.5 to 7.5m; GLONASS 2.8 to 10 m; QZSS 1 m (where available) WAAS, SBAS, and EGNOS enabled
Power	4 AA batteries
Log Capacity	50,000 measurements
Display	Backlit, high-contrast, graphic LCD
Weight	1.4 lbs. (635g)
IP Rating	Display: IP53 Probe: IP67
Probe Head Dimensions	2.4” x 1.4” (6cm x 3.5cm)
Available Rod Dimensions	Turf 1.5” (3.8cm) Short 3.0” (7.6cm) Medium 4.8” (12.2cm) Long 8.0” (20.32cm) Diameter: 0.2” (0.5cm) Spacing: 1.2” (3cm)

* Applies to upgraded units only (see p. 27).

Meter dimensions



Button Functions



ON/OFF or **BACK** button
- Press briefly to power on.
- Press and hold to stay on logo screen.
- Press for 2 seconds to power off.
- Press briefly within a menu to return to prior screen.

MENU or **SELECT** button
- Press to enter available menus.
- Press to select or confirm a menu selection.

DELETE or **UP** button
- Press to move up within a menu.
- Delete last measurement from the running average, counter, and its entry from the internal data log (see page. 14).

READ or **DOWN** button
- Press to move down within a menu.
- From Reading screen, press briefly to make a reading.
- Press and hold to clear the average and reset the sample count to 0.

Display Screens

The TDR 150 has 3 main display screens;
- Startup Information (shown on previous page)
- Reading (figure 1)
- Settings Menu (see p. 8)

Note: **An upgrade is required (see p. 27) to access GNSS and Bluetooth features.**

Startup Information screen

Initially displayed after first powered on.
- Displays firmware version information.
- Press and hold ON/OFF|BACK button to remain on this screen.

Reading screen

Measurements from the sensor are displayed on the Reading screen along with rod size used, soil type, and a reading count with running average.

Press READ to take readings, update Count and the Average.

Indicators:

Battery level icon: upper right corner.

Bluetooth icon: displayed when enabled. A bar appears through it when not actively communicating.

GNSS location icon: When enabled, Transitions from clear to dark as location fix is achieved. Crosshatch appears when WAAS/EGNOS in use.

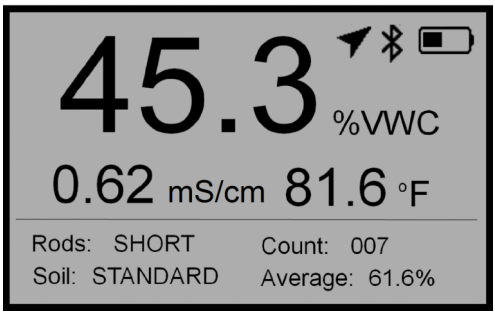


Figure 1.Sample Reading screen

Settings Menu screen
Used for changing device features, setting rod length and working with log files.
Use the arrow buttons to move to the desired option.
Use the **MENU|SELECT** button to toggle option choices.

Clear Average*: Clears the displayed average and count.
Note: Same as a press and hold of the **READ|Down** arrow button.

Rod Length: Select the Rod length See page 4 for options.

Soil Type: Selects the soil type used in measurements:
- Standard: for most mineral soils.
- Hi-Clay: for soils with higher clay content (> 27%).
- Sand: for sand based fields or turf greens.

Clear Logs*: Erases data logs from internal memory.

Save to USB*: Transfers data logs to a USB flash drive if attached.

Backlight: Sets the LCD backlight: ON, OFF, AUTO. In AUTO mode, the backlight will shut off 5 seconds after a button press

+GNSS Location, GNSS Power Save, GNSS Use QZSS: Enable or disable features related to geo-location capability (see p. 12).

+Bluetooth: Enable or disable Bluetooth connectivity to the FieldScout™ Mobile app (See p. 20).

Sound: Enable or disable beep for audible feedback.

Temp Source: Changes displayed temperature from the Soil Sensor to the IR Sensor (optional).

Temp Units: Fahrenheit or Celsius scale.

Moisture Type: Selects displayed moisture mode VWC%, Period, or TDR 300.
- VWC%: Volumetric Water Content with EC compensation.
- Period: Raw sensor reading in microseconds (us).
- TDR 300: VWC without EC compensation

EC Units: EC value (mS/cm) or Salinity Index (see p. 25).

Auto-Off: Power off delay: 15, 30, 45, 60 minutes.

Current Date, Current Time: Displays or changes current values. See p. 13 for details.

Timezone: Offset from Greenwich Mean Time. As the offset changes, the Time and Date will update.

Daylight Savings: ON or OFF.

Calibration*: Overrides factory calibration. See Appendix

Clear User Calibration: Clears the user applied calibration back to factory settings

Factory Defaults*: Resets menu settings and counter to the factory default value.

About: General information (Model and serial number, firmware versions for display and sensor).

Rod Length	None	**Temp Source**	Soil Sensor
Soil Type	Standard	**Moisture**	VWC
Backlight, GNSS, Bluetooth	Disabled	**EC units**	mS/cm
		Auto-Off	15 minutes
Sound	On	**Time Zone**	GMT
Temperature	Fahrenheit		

+ Requires equipment upgrade (see p. 27).
**Pressing Select button for these options brings up an additional screen.*

Meter Operation

Setting up the meter

1. Pull the clear battery transport tab out of the display unit.
2. Select a set of probe rods, screw in, and tighten them to the bottom of the probe block.
3. Set the desired user settings in the settings menu. See the Settings Menu (page 8).

Taking Readings

1. Grip the TDR sensor block.
2. Push down on the block, maintaining a steady downward pressure to drive the rods into the soil until the sensor base is in contact with the soil surface. Be sure not to allow back and forth or side to side movement. This can introduce air pockets into the soil medium which will alter the reading.

Caution: Exercise care not to damage the rods.

3. Press the **READ** button and observe the change in results on the top display.

Meter Care

The FieldScout TDR meter will function properly under normal conditions experienced in field use. The sensor block is sealed and will not be damaged by immersion in water. The display is **not** waterproof, so it should not be used during heavy rainfall or left exposed during irrigation events. If the display does get wet, it should be dried out immediately.

Follow these tips to prolong the life of the device:
- Store in a cool and dry place when not in use.
- Keep the meter and probe rods clean and dry in between uses.
- Remove the batteries if not used for an extended period of time (ie: between seasons).

Battery life

If the battery level is low or a battery is inserted incorrectly, the low battery icon appears on the screen and the display will power off.

Battery life is affected by the enabled features, accessories connected, and the frequency of use. If not needed, the Bluetooth*, GNSS Location* and backlight features can be disabled. The backlight can also be set to AUTO mode (p. 8). This allows enough time to see the reading and conserve the battery. The chart below gives a rough estimate of the number of readings that can be taken given certain configuration parameters.

			Total Readings	
Bluetooth*	**GNSS***	**Backlight**	**Alkaline**	**Lithium**
ON	ON	ON	12,000	24,000
ON	ON	OFF	24,000	35,000
OFF	OFF	OFF	150,000	225,000

***GNSS and Bluetooth functionality is an optional equipment upgrade.**

GNSS (location) Features

The location reference will be stored with the measurement in the data log. The TDR350 has 3 settings related to the geo-location feature. These settings can be enabled or disabled in the Settings Menu (p. 10). Select the desired option and press the **Menu/ Select** button to toggle between the ENABLE and DISABLE options.

GNSS Location
Enable to log Geo-Referenced locations of a soil measurement or disabled to make soil measurements without location referencing. If the GNSS Location is disabled, the date and time information will still be transmitted to the meter.

GNSS Power Save
Disable for expedited geo-referencing and speed of measurements. Enable to reduce power consumption in between distant soil measurements. Note: Enabling will delay the response time of a measurement.

GNSS Use QZSS
QZSS (Quasi-Zenith Satellite System) is a regional system for use in the immediate surrounding areas of Japan, Australia, Guam, Hawaii, Singapore and Bangalore. Enable to add QZSS geo-referenced locations to soil measurements.

GNSS accuracy is improved if the meter remains active for 6 minutes or mores during a data collection session.

Setting Date/Time

By default, the TDR350 gets the date and time from the satellite signal. These values are displayed in the Settings Menu (p. 11). The date and time can also be set manually. When the time and date are set manually, they will over-ride the default value.

Note: When the batteries are removed, the date/time are reset and the meter resumes getting this information from the satellites.

Updating the Date and Time

1. Press the **MENU|SELECT** button to get to the Settings Menu.
2. Press the UP or DOWN arrows to navigate to either the **Current Date** or **Current Time** option.
3. Press the **MENU|SELECT** button to access the Time/Date update screen. There are 3 options.

A. Press the **READ|DOWN** button to download an update from the GNSS satellites. Proceed to an area with a good view of the sky and press the **Menu/Select** button to initiate the process.

B. Press the **DELETE|UP** button to set the date and time manually. The current settings will be displayed. Use the UP and DOWN arrows to adjust the highlighted selection. Press the **MENU|SELECT** button to confirm and proceed to the next parameter. After pressing the **MENU|SELECT** button to set the minutes, the display will return to the Reading screen.

C. Press the **ON/OFF|BACK** button to return to the Settings Menu without making any change.

Optimizing Geo-Referenced Measurements

Achieving optimal results of the optional geo-referencing feature depends on several factors including how long the meter has remained active, atmospheric conditions for the day, which satellite systems are in range and obstacles that may block the reception of the satellite signals. The meter accesses 3 - 4 satellite systems, each with different levels of accuracy available to the general public.

Galileo: within 1 meter of target
GLONASS: within 2.8 - 10 meters of target
GPS: within 3.5 - 7.5 meters of target
QZSS (where available): within 1 meter of target

Additionally, systems such as SBAS, MSAS and others are used along with the meter's own internal satellite mapping data to improve the accuracy further.

Creating the internal satellite maps
The meter relies on internal satellite maps to improve accuracy. These maps are built by the meter during the first three days of consistent use. The meter will track available satellites and hone in on the location of use by referencing the internal maps along with satellites in view. Typically, after the first use, the position accuracy may appear low as the satellite maps are synchronized with the area in which the meter is being used. After the third use, the TDR will have a complete satellite map of the use area and the speed and accuracy of the location referencing will be at its best. Internal maps will re-synchronize if the meter has been out of use for a season or taken out of its usual use areas. This process may result in lower accuracy until the synchronization has completed.

Preparing for a data collection session
Upon initially powering on or enabling the GNSS location feature, expect the first geo-referenced location to take place within a minute or so of operation on a clear day. The GNSS location arrow icon (p.7) will transition from clear to a shaded color as more satellites or higher level of precision are reached. The GNSS location icon gives an indication of the quality of the satellite fix. A minimum of 5 received satellites are necessary for a location fix. Achieving 10 or more satellites will yield high quality position data.

For Best Results
Geo-Location referencing will show the best accuracy when the meter is kept active for 6 minutes or more. The positioning data will be most accurate when the sky is clear, there are few, if any, reflective surfaces, and there is an unobstructed view of the sky. Optimally, the meter should have a clear view of the sky above a 15 degree elevation. When possible, keep clear of buildings, bodies of water, and other reflective surfaces that may distort the signal triangulation. Solid objects, such as trees, buildings, aircraft and even the user themselves can block satellite signals.

Maintenance

Replacing/Re-attaching the Sensor Block (item 6445S):

1. Flip the display so the backing plate is facing up.
2. Remove the 4 corner screws using a Philips Screwdriver.
3. Lift off the base plate, observing the original orientation of the cable.
4. Remove and set aside the foam insert behind the cable.
5. Grip the cable connection and gently pull the cable out
6. Connect replacement sensor cable into the connection.
7. Re-insert the foam insert behind the cable as shown.
8. Guide the sensor cable through the open slot on the base plate (fig. 2).
9. Secure the base plate screws with a Philips Screwdriver.

Figure 1. Sensor cable, batteries and foam insert

Figure 2. Sensor cable fed through slot

Battery Replacement:

1. Flip the display so the backing plate is facing up.
2. Remove the 4 screws on the base using a Philips screwdriver.
3. Lift off the base plate, observing the original orientation of the cable.
4. Install four new AA batteries observing correct polarity by referencing the (+) positive and (-) negative labels.
5. Guide the sensor cable through the open slot on the base plate (fig. 2).
6. Secure the base plate screws with a Philips Screwdriver.

Do not permanently remove the foam plug (fig. 3). It ensures the plug does not become detached.

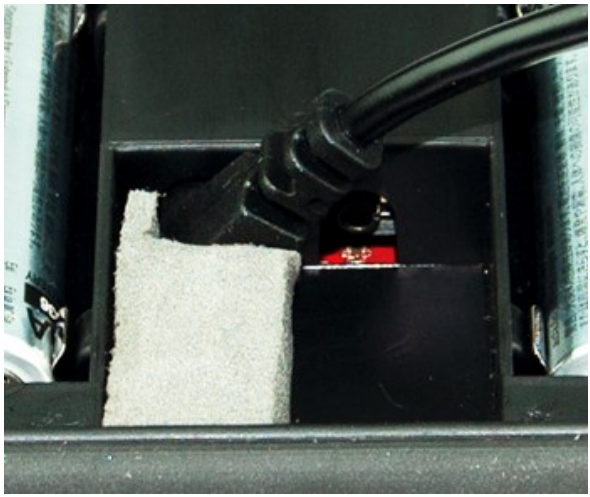


Fig. 3: Foam plug installed

Data Logs

Downloading Data Logs to a USB Flash Drive

1. Connect the flash drive to the meter's USB port. Note: A USB cable is not required or recommended.
2. Press the **MENU|SELECT** button to open the Settings Menu.
3. Press the **READ|Down** arrow button to reach the Save to USB option.
4. Press the **MENU|SELECT** button to select the option.

The data will be saved to the flash drive as a comma-separated text file (.csv) named with the serial number as the filename. These files can be opened with common text-editing or spreadsheet software. If a previous data file exists on the flash drive with the same filename, it will be overwritten. Be sure to save any existing data logs on the flash drive prior to saving a new file.

Erasing the internal Data log

1. Press the **MENU|SELECT** button (p. 7) to open the Settings Menu.
2. Press the **READ|Down** arrow button to reach the **Clear Logs** option
3. Press the **MENU|SELECT** button to select the option.
4. Press **MENU|SELECT** button again to start the process or the **ON/OFF|BACK** button to return back to the menu.

Data Collected

The following information is logged with each reading:

Time, VWC%, Period, EC, Temp_Soil, Temp_Soil(F), Temp_IR, Temp_IR(F), Latitude, Longitude, Satellites, Fix, Rod Length, Soil Type, VWC Mode

Time: MM/DD/YYYY HH:MM:SS based on the GMT offset selected in the **Timezone** option (p.age 9)

VWC%: Volumetric Water Content based on the Moisture Type setting—EC Compensated or "TDR 300" (without EC compensation)

Period: Raw Period result (after any applied user calibration)

EC: Electrical Conductivity in milli-Siemens

Temp_Soil: Soil temperature sensor reading in degrees Celsius

Temp_Soil(F): Soil temperature sensor reading in degrees Fahrenheit

Temp_IR: InfraRed soil temperature sensor reading in degrees Celsius (if equipped)

Temp_IR(F): InfraRed soil temperature sensor reading in degrees Fahrenheit (if equipped)

***Latitude, Longitude:** Geo-referenced coordinate acquired in decimal degrees format. Note: A negative sign may appear indicating South or West coordinates.

Satellites: Number of satellites used in geo-referenced location

***Fix:** GNSS location fix level; 0 - unreferenced, 1 - fixed reference, 2 - fix with additional accuracy correction (SBAS, WAAS, EGNOS)

Rod Length: character is depicted as **L: L**ong (8"), **M**: **M**ed (4.8"), **S: S**hort (3"), and **T**: **T**urf (1.5")

Soil Type: character depicted as **S: S**tandard, **H**: **H**i-Clay, and **D**: sand.

VWC Mode: depicted as V for EC compensated or 3 for non-compensated (TDR-300).

Field Scout Mobile App/ SpecConnect

For upgraded meters (see p. 27), the FieldScout Mobile App can be used to send data directly to the SpecConnect web interface. Data can be viewed on a Smartphone in two formats. In grid mode, the site is divided into a customizable 2-dimensional grid of 3 to 5 rows and 3 to 5 columns. Measurements are taken in each grid cell. Average, color-coded data are displayed on the app (Fig. 1). In freeform mode, a color-coded pushpin icon is placed at every sampling point. If the TDR has a good GNSS location fix (page 7), the app will use the coordinates from the meter. If not, or if the meter's GNSS location is disabled, it will use the internal location of the smartphone. The data from the Pro version of the app is sent instantaneously to SpecConnect. Data can be viewed in map form (fig. 3), exported to a spreadsheet, or viewed as a Trend Report (fig. 4).

More details are available in the user's guide for the app.

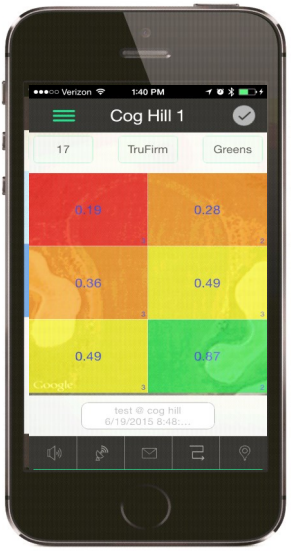


Figure 1. Grid Mode

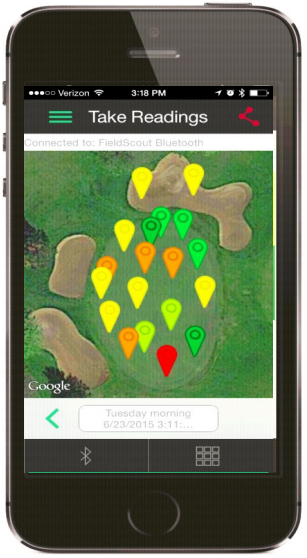


Figure 2. Freeform Mode

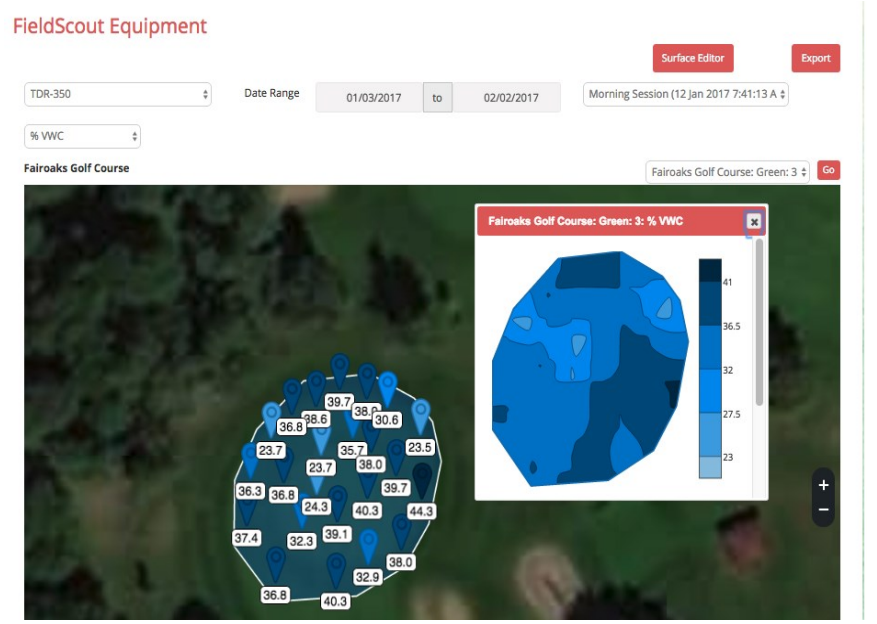


Fig. 3. 2-D Contour Plot in SpecConnect

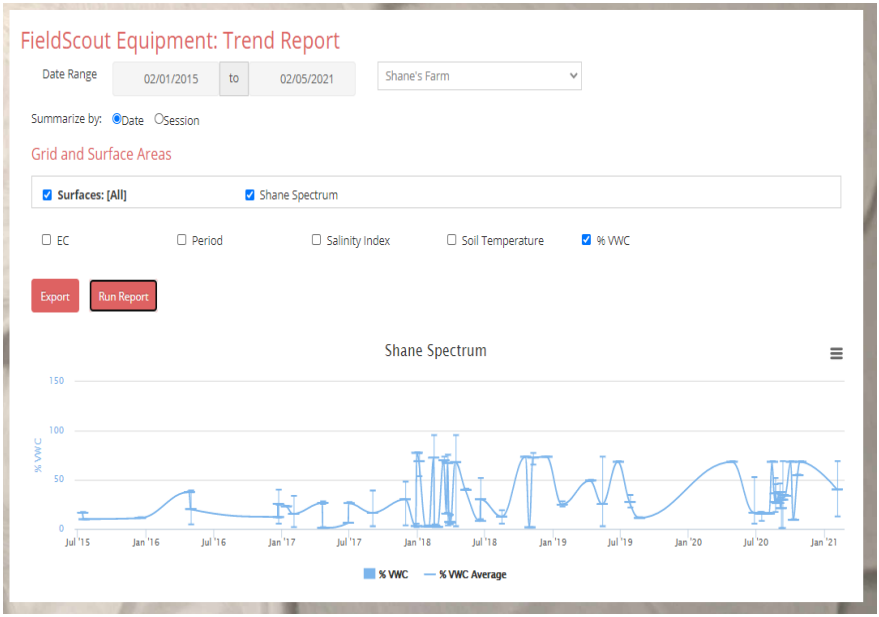


Fig. 4. Trend Report

Pairing With The FieldScout Mobile App

Bluetooth functionality requires an equipment upgrade (p. 27). The internal Bluetooth radio must be paired with the smartphone running FieldScout Mobile. For some smartphone operating systems, it may be necessary to manually enable Location Services.

1. Activate Bluetooth feature on the smartphone.
2. Open the app.
3. Tap the Course/Farm icon. Select an existing course or create, name, and select a new course.
4. Select an existing session or create, name, and select a new session. This will bring up the **Select Session Mode** screen (Fig. 1). Select whether you are using Grid or Freeform (Pro version only) mode to collect data.

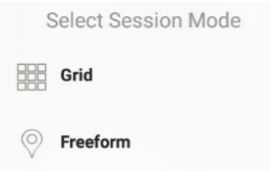


Figure 1. Session Mode screen

5. a. For Grid mode, the **Main Grid** screen (Fig. 2a) will appear. Confirm that the meter you are using appears at the top of the screen. If not, a new session must be created. Tap any of the zones to bring up the **Take Reading** screen (Fig. 2b).

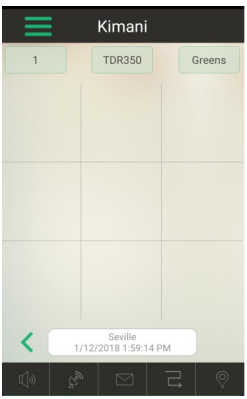


Figure 2a. Main screen

Figure 2b. Bluetooth Connect button (grid)

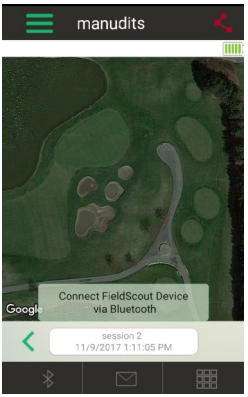


Figure 3. Bluetooth Connect button (freeform)

b. For Freeform mode, the app will immediately transition to the **Take Reading** screen (Fig. 3).

6. Tap the **Connect FieldScout Device via Bluetooth** button. If the Bluetooth feature has not been activated, you will be prompted to do so.
7. The app will search for the Bluetooth device. It should then appear in the list of scanned devices (Fig. 4).

After selecting the device, the App will be ready to take readings.

Note: Although the device appears in the app, it may not appear on the phone's list of Bluetooth devices.

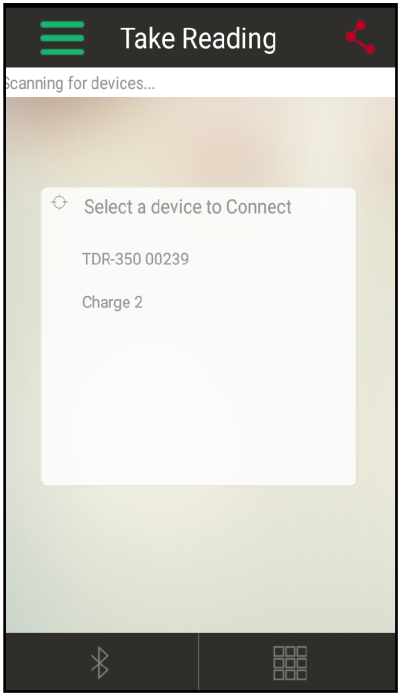


Figure 4. Scanned device list

VWC Measurements

Volumetric Water Content (VWC)
The ratio of the volume of water in a given volume of soil to the total soil volume expressed as a decimal or a percentage. Three soil moisture levels of most importance can be defined as follows:

Saturation: All soil pores are filled with water. The VWC will equal the percent pore space of the soil.

Field Capacity: The condition that exists after a saturated soil is allowed to drain to a point where the pull of gravity is no longer able to remove any additional water.

Permanent Wilting Point: The highest moisture content at which a plant can no longer extract water from the soil.

Additionally, we can define Plant Available Water as the amount of water between Permanent Wilting Point and Field Capacity. One rule of thumb is that irrigation should be initiated when half the Plant Available Water has been depleted.

Time Domain Reflectometry (TDR)
The underlying principal of TDR involves measuring the travel time of an electromagnetic wave along a waveguide. The speed of the wave in soil is dependent on the bulk dielectric permittivity (ε) of the soil matrix. The fact that water ($\varepsilon = 80$) has a much greater dielectric constant than air ($\varepsilon = 1$) or soil solids ($\varepsilon = 3\text{-}7$) is exploited to determine the VWC of the soil. The VWC measured by TDR is an average over the length of the waveguide.

The sampling volume is an elliptical cylinder that extends approximately 3 cm out from the rods. The high frequency signal information is then converted to volumetric water content. High amounts of clay or high electrical conductivity (EC>2 mS/cm) will attenuate the high-frequency signal and affect the reading displayed by the meter. Very high organic matter content will similarly affect the VWC reading.

Electrical Conductivity

Electrical Conductivity

The FieldScout TDR uses EC readings obtained from the same probes used to measure VWC. To improve the VWC measurement accuracy, EC is factored out of the VWC reading. This is a key advantage over its predecessor. The value measured is an average for the entire depth sampled. EC is expressed in units of mS/cm. The EC measured by an electrode is defined as the bulk EC.

The salinity level of soil is an important component of irrigation and nutrient management. The source of soil salts range from the original parent material, additions from natural sources, and management activity. High salt concentration in the soil has a negative effect as plant roots cannot bring in sufficient soil moisture. However, fertilizer exists as salt ions in that same soil solution. Low salt level can result in plants not getting the nutrients needed.

Direct measurement of salt content can only be done by subjecting a field sample to laboratory analysis. Fortunately, the electrical conductivity (EC) is a function of the dissolved salts in the soil. This proxy measurement is possible because, as salts dissolve into the soil, they disassociate into ions which conduct electricity.

Salinity Index

The TDR also has the option to report EC in the form of the Salinity Index. The salinity index is defined as the ratio of the bulk EC to the volumetric water content (expressed as a decimal). For example, if the bulk EC is 0.25 mS/cm and the VWC is 22%, the Salinity Index would be reported as 1.14 (0.25 ÷ 0.22 = 1.14). Therefore, the Salinity Index combines VWC and EC (corrected for temperature) into a parameter that will be less dependent on the sub-saturated water content.

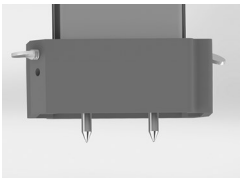
The TDR measures the bulk EC of soil that may or may not be saturated. As the soil dries, the remaining pore space solution becomes more concentrated which increases EC. However, reduced water in the pores leads to a longer and more tortuous path between the sensor electrodes, which decreases EC. The second mechanism dominates. Bulk EC will decrease as soil moisture decreases. EC measurements made at different times are comparable when the moisture content is the same. This is best observed if the readings are always taken when the site is at field capacity - when a saturated soil is allowed to drain to the point where the pull of gravity can no longer remove any additional water.

Optional Accessories

There are two optional items that can be used to expand the capabilities of the TDR350. Visit www.specmeters.com for more information and installation instructions.

Infrared Temperature Sensor (item 6435TS)
Provides an instantaneous and highly accurate temperature reading as an alternative to the existing surface temperature sensor.

TDR Spacer (item 6435SP)

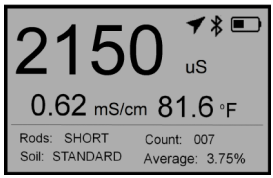


- Placed on the end of the sensor block to aide in identification of how fast and firm the turf greens are. The spacer has two orientations allowing it to work for either desired depth.
- Requires 3.8 cm (1.5”) turf rods.
- For use with firmware version 1.02 or higher
- Allows for the measurement of 1.3cm (0.5") or 2.5cm (1.0") soil depths.

Pilot Hole Maker (item 6430PH)
If the ground is especially hard or compact, you can use a Pilot Hole maker to make 3” holes to aid in starting the insertion of the probe rods.

GNSS Location /
FieldScout™ Connectivity Upgrade (item 6445GBU)
GNSS and Bluetooth capability are not standard features for the TDR150. See p. 27 for instructions on unlocking these features.

Appendix 1: Soil-Specific Reading Correlation



To improve accuracy, correlate TDR period readings with a soil-specific sample set.
VWC data can be correlated by measuring the weight of a known volume of saturated soil as it is gradually dried, by gradually wetting a known volume soil with measured increments of water, or by using a neutron probe. In most cases, gravimetric sampling is performed. This procedure is briefly described below.

1. Establish a number of field sites to sample.
2. Wet each site with varying amounts of water.
3. Obtain FieldScout TDR period reading at each sample site.
4. Extract a known volume of soil at each sample site. Ideally, an undisturbed soil core. Reduce evaporation - store samples in a sealed plastic container.
5. Weigh the wet soil samples.
6. Dry the samples (105^{o}C for 48 hours) and weigh again.
7. Plot sample measurements against FieldScout TDR readings.

Regression analysis is used to develop a formula to correlate TDR readings to the sample data.

Volumetric water content calculations:

VWC = $100*(M_{wet} - M_{dry})/(\rho_w * V_{tot})$

Gravimetric water content calculations:

VWC = GWC $*(\rho_b/\rho_w)$
GWC = $100*(M_{wet} - M_{dry})/M_{dry}$
ρ_b = M_{dry}/V_{tot}

Where:
M_{wet}, M_{dry} = mass (g) of wet and dry soil respectively
V_{tot} = total soil volume (ml)
ρ_w = density of water (1g/ml)

Appendix 2
Troubleshooting

Sensor Function Verification:

Test readings can be taken in three standard environments; air, distilled water, and sand saturated with distilled water. It is important that any troubleshooting be done with distilled water. Readings taken in tap water can differ greatly from the expected results observed in distilled water. Test readings are made in a container of distilled water or saturated sand. The container should have a diameter of at least 3 inches (7.5cm) and should be tall enough so the rods can be completely immersed or inserted.

Readings should be taken with the **Soil Type** to Standard and the correct **Rod Length** selected. The meter should read VWC=0% in air. In saturated sand, it should read between 35% and 45%. The table below shows the approximate ranges of volumetric water content that are expected for the different rod lengths in distilled water.

Rod Length	Water
8 inches (20 cm)	60 - 65%
4.8 inches (12 cm)	70 - 75%
3 inches (7.5 cm)	75 - 80%
1.5 inches (3.8 cm)	65 - 70%

Note: The meter does not read 100% in water because the soil moisture calibration equations were created to be most accurate in the volumetric water contents typically found in mineral soils.

Unable to save data or load firmware from USB flash drive:
Confirm the drive is not full. Verify the drive has FAT or FAT32 format. Firmware should be in the root directory.

"No Sensor" appears on the display:
Confirm that the probe block is securely plugged into the display.

Appendix 3: Updating Device Firmware

Firmware updates may be made available to add or improve the product features. The firmware can be updated using a USB flash drive. Firmware update files can be found on the Spectrum website.

1. Copy the latest firmware update from your PC onto the root directory of the flash drive. The file will not be seen by the meter if it is renamed or stored within a folder on the drive.
2. Power off the meter.
3. Remove the protective cap from the meter's USB port.
4. Insert the flash drive into the meter's USB port. Note: A USB cable is not required or recommended.
5. While pressing the **DELETE|Up arrow** button, press and release the **ON/OFF|BACK** button. The meter will beep.
6. Release the buttons. Note: The display screen will remain blank during the update process. The meter will beep a second time once the process has completed and then reboot to the logo screen. The new firmware will now be displayed below the Spectrum logo.
7. The display will alert the user if further updates are to be made and show a message when completed.
8. Remove the flash drive and replace the USB cover.

Appendix 4: Calibration

The FieldScout TDR is fully calibrated at the factory. Further calibration is not required nor recommended. The meter has internal calibrations for standard, sand, and high-clay soil types which will work for many soils. Each meter will have a small difference in how it responds to identical soil conditions. This can be due to air being introduced while measuring, bent probes, loose probes, sensor drift or component tolerances. The meter allows for adjustments to the calibration to account for these differences. Should the user prefer to perform the calibration; the following are required:

1. A clean glass or plastic container. The container must be at least 10cm (4") wide and at least 5.08cm (2") longer than the length of the TDR rods.
2. A sufficient volume of unused distilled or de-ionized water to fill the above container. **Note: Tap water cannot be substituted**.

Procedure:

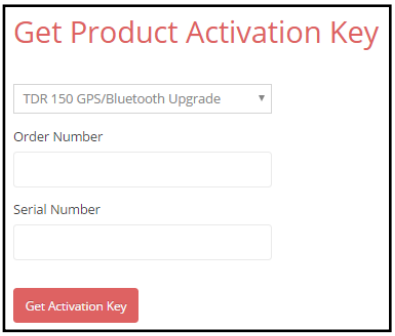
1. Pour all of the distilled/deionized water into the container. The water level must be deeper than the rods currently installed. Note: The water and container must be free of minerals and salts to calibrate properly.
2. From the Settings Menu (page 8), set the rod length to the correct length of the rods currently installed.
3. From the Settings Menu, choose the Calibration option.
4. Press the **Select** button to initiate the calibration process. Follow the display messages.
5. While keeping objects and personnel clear from the area; raise the meter so the rods are in the air. Press the **Menu/Select** button and wait until the meter indicates it is ready.
6. Immerse the rods completely in the deionized or distilled water till the sensor base is in contact with the liquid. Keep the sensor base and rods centered in the container.
7. Press the **Menu/Select** button and wait until the meter indicates it is ready.

The meter will then show that the calibration is complete for that specific rod length. If more than one rod size is being used, a calibration operation must be done for each rod length used.

Appendix 5: Adding GNSS/ Bluetooth Capability

The standard version of the TDR 150 meter comes with the GNSS and Bluetooth capability locked. These features can be unlocked by purchasing item 6445GBU (TDR 150 GNSS/Bluetooth Upgrade). After purchasing the upgrade, the unlock file is downloaded from the following website:
www.specconnect.net/activate

This will bring up the **Get Product Activation Key** screen. Select the "TDR 150 GNSS/Bluetooth Upgrade" option from the dropdown menu. Enter the order number and meter serial number in the next two fields and click the "Get Activation Key button". The program will download the unlock file to your PC. The name of the file will be "150SSSSS.key" where SSSSS is the 5-digit serial number. This unlock key is only valid on the meter for which it was purchased.



The procedure for loading this file onto the TDR 150 is as follows.

1. Copy the unlock file to a USB flash drive.
2. Power off the meter.
3. Insert the flash drive into the meter's USB port.
4. Power up the meter.

If the upgrade is successful, the Startup screen (page 6) will display the text "GNSS/BT Upgrade OK". After this, the GNSS and Bluetooth options will be available in the Settings Menu screen (page 8). If the upgrade is unsuccessful, the Startup screen will display the text "Invalid GNSS/BT Upgrade Key". Confirm that the unlock key on the flash drive corresponds to the meter being upgraded.

Glossary

GNSS: Global Navigation Satellite System. Standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. This term includes e.g. the GPS, GLONASS, Galileo, Beidou and other regional systems

WAAS: Wide Area Augmentation System. Air navigation aid developed by the Federal Aviation Administration to augment the Global Positioning System (GPS), with the goal of improving its accuracy, integrity, and availability.

EGNOS: European Geostationary Navigation Overlay Service. Pan -European satellite navigation system. It augments the US GPS satellite navigation system and makes it suitable for safety critical applications.

SBAS: Satellite Based Augmentation System—used to improve satellite ranging errors

VWC: Volumetric Water Content. The percent of the soil volume that is filled with water. At saturation, the VWC will equal the soil porosity.

EC: Electrical Conductivity. A measure of how well the soil solution conducts electricity. The EC is influenced by the amount of salt and water in the soil.

TDR: Time Domain Reflectometry. A technique for measuring soil moisture content that uses the fact that water has a much higher dielectric permittivity than air, soil minerals, and organic matter.

RE-D EU Declaration of Conformity (DoC) #20210118_1

In accordance with European Parliament and Council Decision No. 768/2008/EC Annex III we, Spectrum Technologies, Inc., a corporation validly organized and existing under the laws of the United States of America, having its principal place of business at 3600 Thayer Court, Aurora IL 60504 USA
declare under our sole responsibility that the below named

Product: FieldScout TDR Soil Moisture Meter
Model Name (Product Number): TDR-150 (6445), TDR-250 (6250), and TDR-350 (6435)

Object of the Declaration:
FieldScout TDR Soil Moisture Meter providing a means for determining the volumetric water content (VWC) of a growing soil.
Specifications:

- Battery powered device (4 x AA batteries)
- 6.9cm (2.7") Backlit LCD Display
- Durable powder coated aluminium frame (TDR-250 and TDR-350)
- Hand-held Display UI and tethered sensor (TDR-150)
- Removable / Interchangeable sensing rods required for proper operation

to which this declaration relates, conform with the relevant requirements of the Harmonized Legislations mentioned below. Specifically, but not limited, to the following harmonized standards and/or normative documents:

Harmonization Legislation:

2014/53/EU Radio Equipment Directive
2011/65/EU Restriction of Hazardous Substances Directive

Article 3.1(a) Safety of Information Technology Equipment

EN 60950-1:2006 + A11:2009 + A1:2010 + A12:2011 + A2:2013 (as applied to internal Bluetooth module Silicon Labs BGM113A-V1 or BGM13P where used)
EN 60950-1:2005(second edition) + Am 1:2009 + Am 2: 2013 (as applied to internal GNSS module Antenova Ltd. M20050-1 where used)

Article 3.1(b) Electromagnetic Compatibility

EN 61000-6-1:2007 Immunity for residential, commercial, and light-industrial environments
EN 61000-6-3:2007 /A1:2011 Emission standard for residential, commercial, and light-industrial environments
EN 55032:2015 /A11:2020 Electromagnetic compatibility of multimedia equipment – Emission requirements
EN 301 489-1 V2.1.1 EMC standard for radio equipment and services; Part 1 (as applied to internal Bluetooth module Silicon Labs BGM113A-V1 or BGM13P and GNSS module Antenova Ltd. M20050-1 where used)
EN 301 489-1 V2.2.3; 2019-11 EMC standard for radio equipment and services; Part 1: Common technical requirements
EN 301 489-3 V2.1.1; 2019-03 EMC standard for radio equipment and services; Part 3: Specific conditions for Short-Range Devices
EN 301 489-17 v3.1.1 EMC standard for radio equipment and services; Part 17 (as applied to internal Bluetooth module Silicon Labs BGM113A-V1 or BGM13P where used)
EN 301 489-17 V3.2.4; 2020-09 EMC standard for radio equipment and services; Part 17: Specif-

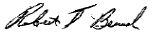
ic conditions for Broadband Data Transmission Systems
EN 301 489-19 V2.1.1; 2019-04 EMC standard for radio equipment and services; Part 19: … GNSS receivers operating in the RNSS band providing positioning, navigation, and timing data (as applied to internal GNSS module Antenova Ltd. M20050-1 where used)
EN 303 413 V1.1.1:2017 Global Navigation Satellite System (GNSS) receivers (as applied to internal GNSS module Antenova Ltd. M20050-1 where used)

Article 3.2 Spectrum Efficiency

EN 300 328 V2.1.1; 2016-11 Wideband Data Transmission Systems; 2.4 GHz Band; Emissions, EMC (as applied to internal Bluetooth module Silicon Labs BGM113A-V1 or BGM13P where used)
EN 300 440 V2.2.1 2018-07 Short Range Devices 1-40 GHz; Emissions; EMC
EN 303 413 V1.1.1: 2017 Satellite Earth Stations and Systems; Global Navigation Satellite System (GNSS) receivers; (as applied to internal GNSS module Antenova Ltd. M20050-1 where used)

Article 3.3 Other Requirements

EN 63000:2018 Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances



Robert T Benesh
Job Title: Electronics Engineer, TDR Product Manager
Email: rbenesh@specmeters.com

UK Declaration of Conformity (DoC) #20210118_2

In accordance with BS EN ISO/IEC 17050-1:2010 we, Spectrum Technologies, Inc., a corporation validly organized and existing under the laws of the United States of America, having its principal place of business at 3600 Thayer Court, Aurora IL 60504 USA
declare under our sole responsibility that the below named

Product: FieldScout TDR Soil Moisture Meter
Model Name (Product Number): TDR-150 (6445), TDR-250 (6250), and TDR-350 (6435)

Object of the Declaration:

FieldScout TDR Soil Moisture Meter providing a means for determining the volumetric water content (VWC) of a growing medium.
Specifications:

- Battery powered device (4 x AA batteries)
- 6.9cm (2.7") Backlit LCD Display
- Durable powder coated aluminium frame (TDR-250 and TDR-350)
- Hand-held Display UI and tethered sensor (TDR-150)
- Removable / Interchangeable sensing rods required for proper operation

to which this declaration relates, conform with the relevant requirements of the Harmonized Legislations mentioned below. Specifically, but not limited, to the following harmonized standards and/or normative documents:

Harmonization Legislation:

2016 No. 1091 The Electromagnetic Compatibility Regulations 2016
2012 No. 3032 The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012

Safety of Information Technology Equipment

EN 60950-1:2006 + A11:2009 + A1:2010 + A12:2011 + A2:2013 (as applied to internal Bluetooth module Silicon Labs BGM113A-V1 or BGM13P where used)
EN 60950-1:2005(second edition) + Am 1:2009 + Am 2: 2013 (as applied to internal GNSS module Antenova Ltd. M20050-1 where used)

Electromagnetic Compatibility

BS EN 61000-6-1:2007 Immunity for residential, commercial, and light-industrial environments
BS EN 61000-6-3:2007 /A1:2011 Emission standard for residential, commercial, and light-industrial environments
BS EN 55032:2015 /A11:2020 Electromagnetic compatibility of multimedia equipment – Emission requirements
EN 301 489-1 V2.1.1 EMC standard for radio equipment and services; Part 1 (as applied to internal Bluetooth module Silicon Labs BGM113A-V1 or BGM13P and GNSS module Antenova Ltd. M20050-1 where used)
EN 301 489-1 V2.2.3; 2019-11 EMC standard for radio equipment and services; Part 1: Common technical requirements
EN 301 489-3 V2.1.1; 2019-03 EMC standard for radio equipment and services; Part 3: Specific conditions for Short-Range Devices
EN 301 489-17 v3.1.1 EMC standard for radio equipment and services; Part 17 (as applied to internal Bluetooth module Silicon Labs BGM113A-V1 or BGM13P where used)
EN 301 489-17 V3.2.4; 2020-09 EMC standard for radio equipment and services; Part 17: Specific conditions for Broadband Data Transmission Systems

EN 301 489-19 V2.1.1; 2019-04 EMC standard for radio equipment and services; Part 19: … GNSS receivers operating in the RNSS band providing positioning, navigation, and timing data (as applied to internal GNSS module Antenova Ltd. M20050-1 where used)
EN 303 413 V1.1.1:2017 Global Navigation Satellite System (GNSS) receivers (as applied to internal GNSS module Antenova Ltd. M20050-1 where used)

Spectrum Efficiency

EN 300 328 v2.1.1 (as applied to internal Bluetooth module Silicon Labs BGM113A-V1 or BGM13P where used)
EN 300 440 V2.2.1 2018-07 Short Range Devices 1-40 GHz; Emissions; EMC
EN 303 413 V1.1.1: 2017 Satellite Earth Stations and Systems; Global Navigation Satellite System (GNSS) receivers; (as applied to internal GNSS module Antenova Ltd. M20050-1 where used)

Article 3.3 Other Requirements

BS EN 63000:2018 Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

Robert T Benesh
Job Title: Electronics Engineer, TDR Product Manager
Email: rbenesh@specmeters.com

Declaration of Conformity
47 CFR § 2.1077 Compliance Information
Unique Identifier: FieldScout Soil Moisture Meter
6435 TDR-350, 6250 TDR-250, 6445 TDR-150

Responsible Party – U.S. Contact Information

Spectrum Technologies, Inc., 3600 Thayer Ct. Aurora IL 60504
Phone: (800) 248-8873 or (815) 436-4440 Fax (815) 436-4460
E-Mail: info@specmeters.com Web: www.specmeters.com

Directive/Standard:
FCC Part 15: 2020: Emissions for Unintentional Radiators for USA (ANSI C63.4:2014)
ICES-003:2019: ITE Emissions for Canada (ANSI C63.4:2014)

FCC Compliance Statement
This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an output on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced RF technician for help.

This device contains licence-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's licence-exempt RSS(s). Operation is subject to the following two conditions:
(1) This device may not cause interference.
(2) This device must accept any interference, including interference that may cause undesired operation of the device.
This Class (B) digital apparatus complies with Canadian ICES-003.
Cet appareil numériqué de la classe (B) est conformé à la norme NMB-003 du Canada.

Proper Disposal of Waste Electrical and Electronic Equipment

This symbol when found on the product or packaging indicates that this product shall not be treated as common waste and that an effort to recycle materials should be made or may be required. Disposal of used and depleted electrical & electronic equipment may be subject to local laws and regulations for proper collection and recycling initiatives in the local area. This is applicable to areas within the European Union and other participating countries including the USA. The recycling of materials will help to conserve natural resources and prevent negative consequences of inappropriate waste handling at the end of a product's usable life. For more information about the recycling of waste electrical and electronic equipment, please contact your local civic office, waste disposal service, or the shop where the item was purchased.

Warranty

This product is warranted to be free from defects in material or workmanship for **two** years from the date of purchase. During the warranty period Spectrum will, at its option, either repair or replace products that prove to be defective. This warranty does not cover damage due to improper installation or use, lightning, negligence, accident, or unauthorized modifications, or to incidental or consequential damages beyond the Spectrum product. Before returning a failed unit, you must obtain a Returned Materials Authorization (RMA) from Spectrum. Spectrum is not responsible for any package that is returned without a valid RMA number or for the loss of the package by any shipping company.

Changes, modification, or use of this product beyond the scope of this instruction manual may void the warranty and/or void the user's authority to operate the device.

Spectrum®
Technologies, Inc.

3600 Thayer Ct.
Aurora IL 60504
(800) 248-8873 or (815) 436-4440
Fax (815) 436-4460
E-Mail: info@specmeters.com
www.specmeters.com

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