

TOPseven LPS 4

User Manual

LPS Inspection Set

TOPseven Hardware – Model TSLPS22

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1.1. Revision History

Rev. No.	Date	Description of Change
Rev 0.1	15.07.2024	Initial draft
Rev 0.2	26.07.2024	General review and amendments implemented
Rev 0.3	08.08.2024	General review and multiple amendments included
Rev 0.4	03.09.2024	A5 formatting and cross-reading
Rev 1.0	11.09.2024	Amendments included
Rev 1.1	17.12.2024	Amendments updated and specified
Rev 1.2	17.02.2025	Further amendments updated and specified

Legend:



Notes are used to highlight special operating conditions or steps of a procedure.



Warnings are used to highlight procedures which, if not strictly observed, may result in personal injury or loss of life.



Hints.

2. Introduction

The next generation of wind turbines is planned to feature hub heights of 200 meters and rotor diameters exceeding 230 meters. A notable example is the General Electric Haliade-X, one of the largest offshore wind turbines currently in operation, which has been installed with a hub height of 150 meters and a rotor diameter of 220 meters. These massive structures present significant challenges for inspection and maintenance, particularly when using traditional rope access methods, which are both time-consuming and require considerable effort to ensure safety.

Inspecting wind turbines, especially those of such immense scale, is a complex task. Traditional inspection methods involve rope access technology, which means technicians must physically climb and inspect the structures. This method is not only hazardous but also inefficient, requiring substantial time and manpower to complete. With the increasing size and number of wind turbines, there is a growing need for more efficient, safer, and more cost-effective inspection solutions.

Autonomous technologies, such as drone-based inspection methods, are revolutionizing the field of wind turbine maintenance. TOPseven's technology is in its 4th generation (**TOPseven LPS 4**) and provides a non-contact, non-destructive means of inspecting the Lightning Protection System (LPS), significantly reducing the risks and time associated with traditional methods. Drone-based inspection provides a cutting-edge solution that promises to play a crucial role in the future of wind turbine inspection.

TOPseven's method employs a novel and patented (i.e. **EP 3 596 570 B2, US 11 880 118 B2, US 11 435 650 B2, CN 110637264 B, ES 2890855 T5, WO2018166645A1** and others) approach to inspecting the LPS on wind turbine blades. Instead of applying a voltage and measuring the electrical resistance, this technique involves injecting an alternating current (AC) at a frequency of 13.565 MHz into the LPS conductor. The injected current

creates a standing wave along the rotor blade resulting in minima/maxima at $\lambda/2$, that is approximately every ~11 m.

If there is any discontinuity or change in the impedance along the down conductor, the amplitude of the standing wave and the positions of the minima will change due to phase shifts. If the down conductor is completely disconnected, the standing wave will begin from the disconnection (resembling the side condition of an open end) and after that there will not be any near field around the rotor blade making it possible to find the position of fault. Generally, the reflection coefficient changes both in phase and amplitude as the end load Z_L and thus the impedance change.

Further details, e.g. standing wave characteristics (simulation), discussion and interpretation, can be requested from and discussed with our Customer Support.

The non-contact nature of the TOPseven method ensures that the inspection process is non-destructive and does not interfere with the turbine's operation. It significantly reduces inspection time and enhances safety by eliminating the need for manual climbing and direct interaction with the turbine components outside the nacelle. It is only necessary to access the LPS cable at the rotor blade root to install the individual TOPseven Signal Generators, respectively. The high-frequency AC current permits precise detection of any discontinuities in the LPS conductor, ensuring the reliability and effectiveness of the lightning protection system.

This manual aims to provide a comprehensive guide on the usage, features, and compliance information for the TOPseven drone-based LPS inspection method. It is intended to help users understand the product's functionality, benefits, and operational procedures. By following the instructions and guidelines outlined in this manual, users can effectively utilize the product for (e.g. onshore) wind turbine inspections while ensuring high safety and efficiency standards are maintained.

The use of a specific set of tools that guarantee reliable results is imperative so LPS measurements can be undertaken effectively. In addition to a

sophisticated DJI Enterprise drone (or other drone, including potentially a DJI RTK Base Station and the TOPseven Camera for visual inspection), a comprehensive hardware setup is needed. This setup includes a laptop, three TOPseven Signal Generators, a TOPseven Field Sensor, and the TOPseven Charging Case which also acts as the transport case. These components form the backbone of the measurement process, ensuring not only the accuracy of the data collected but also the overall effectiveness of lightning protection strategies. In the following sections, the specifics of the equipment required are explained.



Figure 1: Possible (minimal) TOPseven Drone Hardware with support equipment for LPS inspection.

2.1. Product Overview

The inspection process utilizes a drone equipped with the TOPseven Field Sensor. This sensor is positioned at a certain distance from the rotor blade and measures the near field emitted due to the induced current. By analyzing the near field around the rotor blade, the current distribution

along the LPS down conductor can be determined. This distribution helps identify any discontinuities or faults in the LPS down conductor.

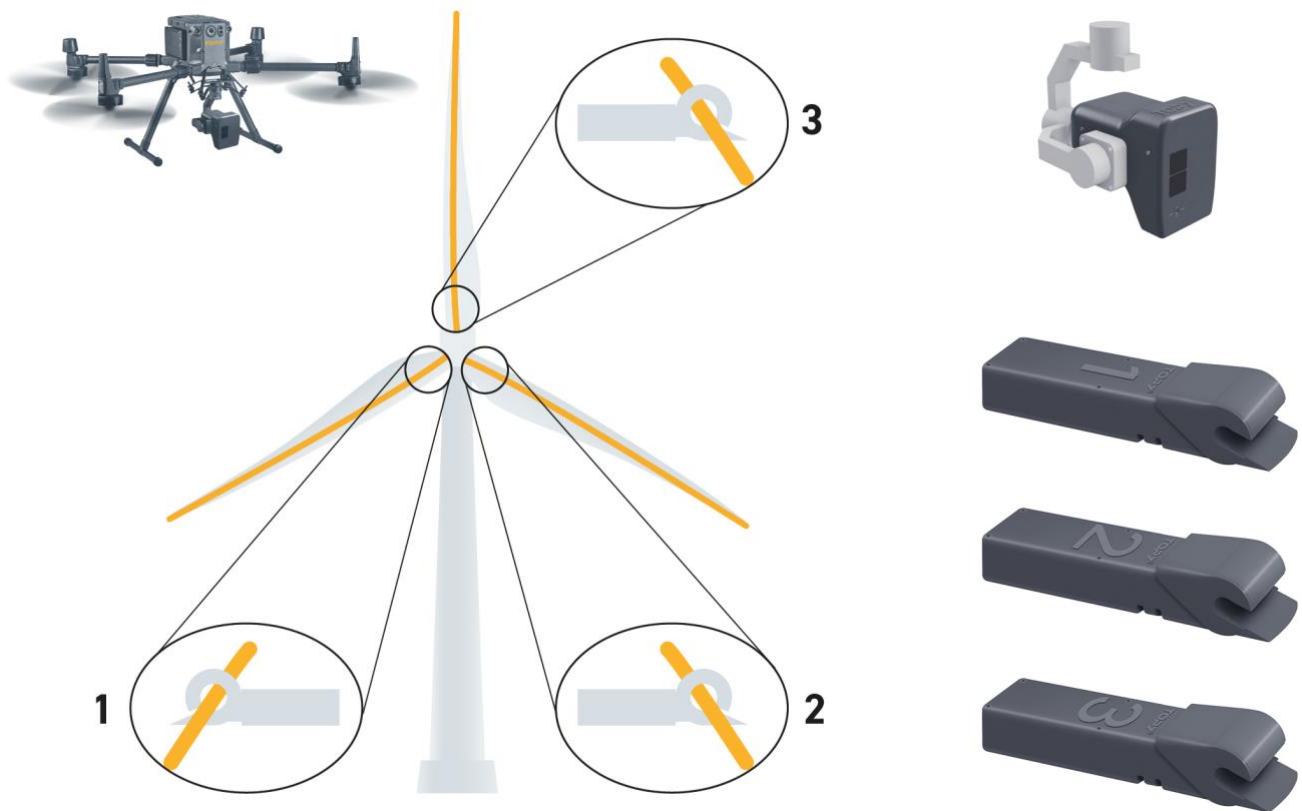


Figure 2: Illustration of the TOPseven product components and the intended use. From left to right: DJI M300 RTK or DJI M350 RTK with TOPseven Field Sensor as payload, illustration of the TOPseven Signal Generators attached to the LPS in a wind turbine, TOPseven Field Sensor with gimbal, the three TOPseven Signal Generators.

Key Features:

1. **Drone-Based Inspection:** Utilizes drones for **non-contact, non-destructive** inspection of wind turbine blades to locate faults.
2. **AC Current Injection:** Injects a 13.565 MHz AC current into the LPS conductor to create a standing wave for the measurement, this standing wave is highly sensitive to impedance changes.



Note: Only fit the TOPseven Signal Generators to LPS down conductors on wind turbine rotor blades and not to any other cable or similar.

3. **TOPseven Field Sensor:** Equipped with a near field sensor to measure the field emitted due to the induced current.
4. **Automated Flight:** The flight path for the drone is automated, ensuring thorough and consistent inspections.

3. Safety Information

3.1. General Safety Instructions

Please adhere to the following safety instructions to ensure safe operation and to prevent accidents:

1. **Read the Manual Thoroughly:** Before using the product, read this manual carefully and make sure you understand the information and instructions it contains.



Do Not Open Any Devices: Under no circumstances should any of the devices be opened. Opening the devices can lead to serious injury, damage to the equipment, and render void the warranty.



Note: Unauthorized opening or tampering with the equipment may also result in legal action. Always refer servicing to qualified TOPseven personnel.

2. **Qualified Personnel:** Ensure that only trained and qualified personnel operate the equipment (TOPseven training certificate). Also ensure that personnel are qualified to work on wind turbines.
3. **Personal Protective Equipment (PPE):** Wear appropriate PPE, including safety helmet, gloves, and protective eyewear, especially while inspecting wind turbines.
4. **Environmental Awareness:** Be aware of the surrounding environment and ensure that the area is safe for drone operation. Also always check for any local or temporary flight restrictions in the area of the inspection.
5. **Check Equipment:** Regularly check the drone and associated equipment for any signs of damage or wear before each use.

6. **Emergency Procedures:** Familiarize yourself with emergency procedures if equipment failure occurs. TOPseven can provide additional information on request from our Customer Support.

7. **Training:** All operators must undergo comprehensive training conducted by TOPseven certified trainers to guarantee the safe and effective operation of our drone and associated equipment. All operators must obtain TOPseven certification, which ensures they are proficient in handling and operating our LPS inspection equipment. This certification process is designed to prevent misuse and minimize the risk of handling errors.



8. **Communication:** Maintain clear communication with team members during operations to ensure safety and coordination.

9. **General Operation:**

a. **Operating in the Open Category A3 (EU):** Operating in the open category A3 is feasible as TOPseven has not altered the drone (e.g. DJI) hardware (UAV // SRC) or software. The software developed by TOPseven operates with the lowest priority in the software hierarchy, ensuring that all safety features of the drone (e.g. DJI) hardware and software remain fully functional.



Abort Procedure: The remote pilot (operator) can abort the automated flight at any time and instantly regain full control of the UAV. **Caution:** Although the flight is automated, the pilot must remain alert and aware of the environment.

c. **Software Functionality:** The TOPseven Software primarily calculates flight waypoints. The manufacturer of the drone (e.g. DJI) has FCC-certified its UAS with all functions, including waypoint calculation and the use of non-DJI payloads via the DJI PSDK. TOPseven is registered as an SDK developer in the DJI Developer Center.

3.2. Specific Warnings and Cautions

Electrical Hazards

- **Connection:** Only connect the TOPseven Signal Generators to down conductors for the LPS or the TOPseven Bridging Cable (not part of this product) possibly with the aid of TOPseven Wedges (not part of this product) inside the nacelle of a wind turbine.
- **Low Voltage:** The equipment operates with a low voltage. However, always ensure that the power is turned off before performing any maintenance or adjustments.
- **Current Injection:** Be cautious while injecting AC current into the LPS conductor. Ensure all safety protocols are followed to avoid electric shock.

Drone Operation

- **Flight Safety:** Ensure the drone flight path is clear of obstacles and unauthorized personnel.
- **Regulatory Compliance:** Ensure compliance with all local and international aviation regulations and guidelines related to drone operations.



Battery Handling: Handle battery powered equipment with care. Avoid exposure to high temperatures and ensure proper disposal according to local regulations. Use only the chargers recommended by the OEM. Regularly check TOPseven Signal Generators for signs of wear or damage and follow proper charging procedures to avoid overheating or explosions.

- **Weather Conditions:** Do not operate the drone in adverse weather conditions such as high winds (>15 m/s), heavy rain, dense fog, snow or lightning. These restrictions are recommended to prevent the malfunction of the drone's (e.g. DJI) obstacle avoidance sensors.

- **Emergency Landing:** Ensure that there are designated safe areas for emergency landing if necessary. Be prepared to take manual control of the drone at any time and to execute a safe landing if automatic system failures occur.

High Temperatures

- **Heat Generation:** Components may become hot during operation. Allow the equipment to cool down before handling or storing.
- **Storage Conditions:** Store the equipment in a cool, dry place to prevent overheating and degradation. Only use the original charging case.

Data Security

- **Data Storage:** Ensure that all data collected during inspections are securely stored and backed up using TOPseven Navigator, TOPseven Cloud and TOPseven Inspector. Follow TOPseven's data management protocols to protect sensitive information.
- **Access Control:** Only permit authorized personnel to access data storage systems to prevent unauthorized access and data breaches.

Contact with Water, Acids and Oils

- **Water:** Ensure that the TOPseven Signal Generators, TOPseven Field Sensor, and TOPseven Charging Case are kept dry at all times. Exposure to water can cause electrical malfunctions, short circuits, and permanent damage to the equipment. The equipment is not designed to withstand direct exposure to water spray or rain. If any component is exposed to such conditions, turn it off immediately and contact TOPseven Customer Support for further instructions.
- **Acids:** Avoid exposing the equipment to any acidic substances. Acids can corrode metal parts, damage electronic components, and compromise the functionality of the system. If accidental contact with acids occurs, rinse the affected area with a suitable neutralizing agent if safe to do so and seek assistance from TOPseven Customer Support.



- **Oils:** Prevent the TOPseven Signal Generators, TOPseven Field Sensor, and TOPseven Charging Case from coming into intense contact with oils. Oils can seep into the electronic components causing insulation failure and potential overheating. If any part of the equipment is exposed to oil, clean it carefully with a dry cloth and check for any operational issues. If necessary, contact TOPseven Customer Support for detailed advice.

3.3. Electrical Safety

- **Power Off:** Always turn off the power and disconnect the equipment from the power source before performing any maintenance.
- **Insulated Tools:** Use insulated tools while working with electrical components to prevent electric shock.
- **Avoid Water:** Keep the equipment away from water or other liquids to prevent short circuits and shocks.
- **Grounding:** Ensure proper grounding of the equipment to avoid static discharge and potential hazards.
- **Cable Management:** Ensure all cables are properly managed and do not present tripping hazards and are not damaged.
- **Regular Inspections:** Conduct regular inspections of electrical components and wiring to identify and address any signs of wear, damage, or potential failure.
- **Safety Labels:** Make sure you understand and follow the information on all safety labels and warnings on the equipment to prevent accidental misuse.

3.4. Handling and Storage

- **Proper Storage:** Store the TOPseven Hardware in a dry, dust-free environment. Avoid extreme temperatures and direct sunlight.

- **Handling during Transport:** While transporting the TOPseven Hardware, handle it with care to prevent damage to sensitive components.
- **Handling during Usage:** Always use the safety leash to secure the TOPseven Signal Generators. Using only the clamp for mounting the TOPseven Signal Generator on the LPS down conductor cable is not enough. The leash will prevent the TOPseven Signal Generator accidentally falling into the rotor blade, which could result in significant damage or injury. If the TOPseven Signal Generator is dropped on the ground, even if there is no visible damage, immediately contact TOPseven Customer Support for further inspection and guidance. Ensuring the equipment is in correct working order is crucial for safe and effective operation.
- **Battery Storage:** Store TOPseven Signal Generators in a cool, dry place away from direct sunlight and high temperatures. Charge batteries only in the charging case provided.

**NOTE**

Note: The integrated Battery Management System (BMS) regulates the battery health status; the battery level can **only** be read if power is supplied to the charging case.

- **Regular Maintenance:** Perform monthly maintenance checks on the TOPseven Hardware to ensure its correct long-term operation and optimal performance.
- **Cleanliness:** Keep the TOPseven Hardware clean and free from dust and debris. Use a soft, dry cloth for cleaning.
- **Transportation:** Only use the TOPseven Charging Case, which is part of the product, while transporting the equipment to prevent damage.
- **Inventory Checks:** Regularly check your inventory to ensure all components are present and in correct working order, i.e. check for
 - Cracks, dents, or other physical damage
 - Frayed or damaged cables and connectors
 - Missing screws or loose parts

- Signs of overheating or corrosion
- **Report:** After completing the inventory check, update your inventory records to reflect the current status. Note any:
 - Damaged or missing items
 - Components requiring maintenance or replacement
 - Items that have been repaired or replaced since the last check

Document the results of each inventory check, including any issues found and actions taken. Report any significant problems to the relevant personnel or management for further action.



If doubts arise, always contact TOPseven Customer Support. By following these safety instructions, you will ensure the safe operation of the TOPseven Hardware, prolonging its lifespan and maintaining its performance.

4. Product Description

4.1. TOPseven Signal Generator

Description and Purpose:

The TOPseven Signal Generator is a specialized device designed to induce a tuned signal into the Lightning Protection System (LPS) conductors on wind turbine blades. This non-invasive method permits the generation of a field along the rotor blade, which is necessary for the measurement and inspection process. Its primary purpose is to facilitate the detection of discontinuities or faults in the LPS by generating a standing wave that can be measured by the TOPseven Field Sensor.



Note: For a functional inspection it is necessary that the tower is grounded downward from where the TOPseven Signal Generators are mounted.

Key Components and Features:

- **High-Frequency Signal Generation:** Operates at a frequency of 13.565 MHz, which is in the worldwide license-free ISM band (local deviations are possible).
- **Coil Induction:** Utilizes a coil for signal induction, ensuring that the process does not require any physical alterations to the LPS conductor. This approach preserves the integrity of the system while enabling effective signal transmission.



The lightning protection cable at the mounting point of the TOPseven Signal Generator does not have to be interrupted or disconnected from the ground. The probe is simply pushed around the cable and fixed with the clamp at an accessible point.

- If the cable is rigid, the ring can also simply be placed on the cable and then only needs to be fixed in place using adhesive tape.



The signal (generator output) is calibrated (feedback loop) with the induction ring during production to produce a constant output power. Problems with mismatching of standing waves with different rotor blade setups and lengths will therefore not occur.

- With optimal matching, there are no oscillations or spurious waves (harmonics) - the signal propagates only in the specified extremely narrow frequency band.
- Uniform, repeatable measurement behavior with identical blade designs.
- **LoRa Communication:** Equipped with a LoRa (Long Range) communication module, the TOPseven Signal Generator ensures reliable, long-distance communication with the TOPseven Field Sensor. LoRa's low-power, wide-area network capabilities make it ideal for the extensive environments typical of wind turbine installations. During high frequency signal generation, the LoRa transmission of the TOPseven Signal Generator is inactive.



Power Supply: Powered by a 3-cell Li-Ion battery (11.1 V) that provides sufficient power for extended operation. The battery is embedded and **NOT** designed for replacement or maintenance by the user. Battery replacement and maintenance are to be undertaken by TOPseven Support.

- **Enhanced Portability:** Lightweight and ergonomically designed for ease of handling and installation by field technicians.

4.2. TOPseven Field Sensor

Description and Purpose:

The TOPseven Field Sensor is a highly sensitive field sensor designed to measure the field generated by the TOPseven Signal Generator along the wind turbine blade. This sensor measures the near field signal, and the data is used to analyze the current distribution and detect any discontinuities (impedance changes) in the LPS down conductor. The purpose of the sensor is to provide accurate, non-contact measurements of LPS effectiveness.

Key Components and Features:

- **Field Measurement:** Utilizes a sophisticated sensor to measure precisely the near field emitted by the LPS down conductor. This capability enables accurate assessment of the conductor's integrity without direct contact, ensuring minimal impact on operational efficiency.
- **High Sensitivity and Narrowband Filtering:** Features a highly sensitive detection system with narrowband filtering to isolate the desired signal frequency and reduce noise.
- **Processing Unit:** Equipped with a processing unit, enhancing computational capabilities while maintaining a compact form factor. The processing unit facilitates high-speed data processing and analysis, crucial for real-time monitoring and diagnostics during inspection flights. The data recorded is transferred wirelessly after the inspection flight to the TOPseven Pilot App on the Remote Control and then to TOPseven Navigator.
- **LoRa Communication:** Integrates a LoRa (Long Range) communication module for seamless, long-distance data transmission from the drone through the TOPseven Field Sensor to the respective TOPseven Signal Generator.
- **Durable and Weather-Resistant:** Built with durable, weather-resistant housing to withstand the harsh environmental conditions

prevalent in wind turbine installations. The sensor's robust design ensures reliable performance in diverse operational scenarios.

- **Compact and Lightweight Design:** Designed for portability and ease of deployment, enabling efficient integration with the drone and minimizing setup time in the field.
- **Laser Range Finder:** Provides precise distance measurement and spatial awareness, enhancing the accuracy of the inspection process, especially while maintaining an exact distance from the payload to the blade surface.
- **Camera:** Equipped with a wide-angle lens camera to capture a broader area during inspections, ensuring comprehensive coverage and accuracy during the inspection process (AI orientation correction) and control via a live view during inspection.
- **SD Card Slot:** Includes a SD card slot for easy data storage and retrieval, permitting a convenient calibration process.

4.3. TOPseven Charging Case

Description and Purpose:

The TOPseven Charging Case is designed to securely store and charge the various components of the TOPseven Hardware. This case ensures that all equipment is safely transported and readily available for use, enabling simple transport and protecting the components from damage if packed properly.

Key Components and Features:

- **Integrated Battery Management and Charging System:** Enables simultaneous charging of all three TOPseven Signal Generators, ensuring all components are fully charged and ready for operation. USB-C charging unit which supports 110 V and 220 V and fully charges the TOPseven Signal Generators in less than 2 hours.
- **Protective Storage:** Provides compartments and padding for securely stowing the TOPseven Signal Generators, TOPseven Field Sensor, and

accessories, protecting them against minor physical damage (light shocks, vibration, scratches). The TOPseven Charging Case cannot provide protection against severe physical impact (dropping, powerful shocks, large amplitude vibration or similar).

- **Portable Design:** Features a rugged, portable design with handles for easy transportation to and from the inspection site.
- **Charge Indicators:** Includes small display above each charging slot. The charging status can be displayed by pressing the state button for each charging slot, ensuring users can easily monitor battery levels.



Note: The status of individual Signal Generators can only be read by pressing the respective button while the case is supplied with power.

4.4. Package Contents

The TOPseven LPS Inspection Set package includes the following items (see next illustration):

- **TOPseven Signal Generators:** 3 units
- **TOPseven Field Sensor:** 1 unit
- **USB-C Charger:** 1 unit
- **TOPseven Charging Case:** 1 unit
- **User Manual:** 1 copy

By ensuring all these components are included and properly maintained, users can maximize the efficiency and effectiveness of the TOPseven drone-based inspection set for wind turbine LPS measurement and inspection.

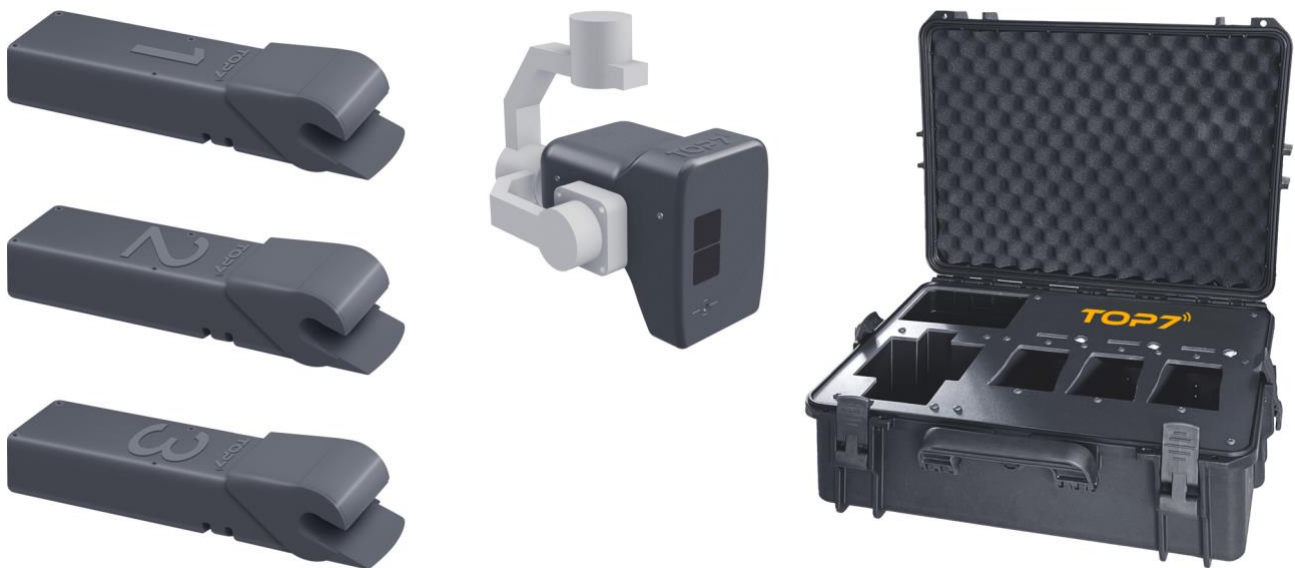


Figure 3: 3x TOPseven Signal Generators, 1x TOPseven Field Sensor, 1x TOPseven Charging Case. The USB-C Charger and User Manual are not shown.

5. Installation and Setup

Each TOPseven LPS Inspection Set is uniquely identified by a 4-digit serial number (SN), ensuring precise tracking and management of the equipment. The sub-components within each set have corresponding numbers appended to the 4-digit serial number to denote their specific roles: "0" for the TOPseven Field Sensor, "1," "2," and "3" for the respective TOPseven Signal Generators, and "4" for the TOPseven Charging Case. The serial numbers can be found on the labels on each component.



Be aware: It is important to note that there is **no** interchangeability between TOPseven LPS Inspection Sets. Each set is designed to work exclusively with its corresponding components, ensuring optimal performance and accuracy. This unique identification system permits the operation of multiple TOPseven Inspection Sets in the field without any limitations or confusion.

5.1. Unpacking

Follow these steps to ensure the TOPseven LPS Inspection Set is unpacked properly and ready for setup:

1. **Inspect Package:** Verify that the package is intact upon receipt. Check for any signs of damage during shipping.
2. **Check Contents:** Ensure all components listed in the package contents are present:
 - **TOPseven Signal Generators:** 3 units
 - **TOPseven Field Sensor:** 1 unit
 - **USB-C Charger:** 1 unit
 - **TOPseven Charging Case:** 1 unit
 - **User Manual:** 1 copy
3. **Inspect Components:** Examine each component for any visible damage or defects. Contact TOPseven Customer Support if you find any issues.
4. **Read Documentation:** Read this User Manual for an overview of the system components and initial setup instructions. The user is referred to the respective drone and TOPseven Ecosystem user manuals for information about the use of the overall system; these manuals are accessible through the TOPseven Customer Center.

5.2. Preparation Instructions

Follow these detailed instructions to prepare the TOPseven LPS Inspection Set:

1. **Prepare TOPseven Signal Generators:**
 - Place each TOPseven Signal Generator on a flat, stable surface.
 - Ensure the clamps around the coils are securely attached and free to move, but not loose, on all TOPseven Signal Generators.
2. **Prepare Field Sensor:**
 - Remove the TOPseven Field Sensor carefully from the case.

- Handle the sensor with care to avoid damaging the components for measuring the near field, the distance sensor or the wide-angle lens.
- Remove the gimbal cap and any lens protector and store these properly in the case. Always replace the cap and protector after usage and during storage.
- Rotate the gimbal connector to the unlocked position and insert the gimbal. Then rotate the gimbal to the locked position. Apply even, firm rotating force when attaching and detaching the gimbal.

3. Secure Power Supply:

- Connect the USB-C charger to a suitable power source and the USB-C connector to the TOPseven Charging Case.
- Check the battery status and charge the internal batteries in the TOPseven Signal Generators until fully charged for first usage.

The charge status of the TOPseven Signal Generators must be checked before driving into the field. The charge status can only be checked using the TOPseven Charging Case while the case is connected to a power supply. Press the button next to the individual display. The display shows the charge status as a percentage and thus indicates the progress during the charging process for the related TOPseven Signal Generator. For an LPS inspection, the TOPseven Hardware and Software must be fully setup in advance.

6. Operation Instructions – General

The detailed manuals for all the peripheral devices (Hardware) as well as the Software for the overall interaction with the full TOPseven Ecosystem can be found in the TOPseven Customer Center. These include manuals for TOPseven Inspector, TOPseven Navigator, TOPseven Pilot App as well as all the manuals required to operate the ecosystem as a whole. These details are not part of this manual and are only briefly described and illustrated below.



General procedure (**Note: This procedure may vary slightly for different wind turbines and different versions of the software for the TOPseven Ecosystem – please contact Customer Support for help**):

1. Set up the TOPseven Hardware.
2. The wind turbine is stopped in the 12 o'clock position. It must be ensured that the position of the rotor cannot change until the inspection is completed.
3. After ensuring that the rotor can no longer move, the calibration can begin. Details can be found in the manual for TOPseven Navigator, which is available in the TOPseven Customer Center.
4. One or two employees ascend to the nacelle with the three TOPseven Signal Generators to install them.



Please be sure to comply with all the necessary HSE requirements while working in the WTG.

5. Attach the three TOPseven Signal Generators one after the other one in the different blade positions (4, 12 and 8 o'clock).
6. Then switch on the TOPseven Signal Generators. Once switched on, the LED in the power-on button lights up.



NOTE: For some wind turbines, additional attachment equipment (TOPseven Bridging Cable/TOPseven Wedges) may be required. Detailed instructions for different wind turbines can also be found in the TOPseven Customer Center. The nacelle should be left during the inspection flight.

7. Note down the rotor blade numbers as well as the corresponding numbers of the TOPseven Signal Generators according to the blade position. This is necessary for the assignment in TOPseven Navigator. Always number as viewed from the front outside the rotor.
8. After calibration, the non-contact lightning protection measurement is carried out with the TOPseven Field Sensor attached to the drone (e.g. DJI). Instructions and further details can be found in the User Manual for the TOPseven Pilot App, which can be found in the TOPseven Customer Center. The overall communication protocol and inspection sequence is fully automated; no customer or pilot interaction is needed.
9. After the inspection with the TOPseven LPS Inspection Set has been completed, the TOPseven Hardware is removed from the wind turbine generator in reverse order of installation.

At the end of the inspection, all data are transferred from the TOPseven Pilot App to TOPseven Navigator for later upload to the TOPseven Cloud. The data are analyzed in the Backoffice via TOPseven Inspector.

Step No.	Description of Step (these steps may vary for different versions of the TOPseven Pilot App & TOPseven Navigator)
1	The DJI Matrice 300 / 350 (or other drone) starts the automated LPS flight after calibration.
2	The drone flies to the root of rotor blade 1.
3	The drone stops at the root of rotor blade 1. The TOPseven Signal Generator signal output is activated remotely by the TOPseven Field Sensor.
4	Flight to the tip of rotor blade 1.
5	TOPseven Field Sensor checks if the TOPseven Signal Generator output is still activated. The Inspection flight starts.

6	The drone stops at the root and the TOPseven Signal Generator is switched off by the TOPseven Field Sensor. Data collection is complete.
7 – 10	Repeat step 3 – 6 for blade 2
11 – 14	Repeat step 3 – 6 for blade 3
15	The drone lands automatically.

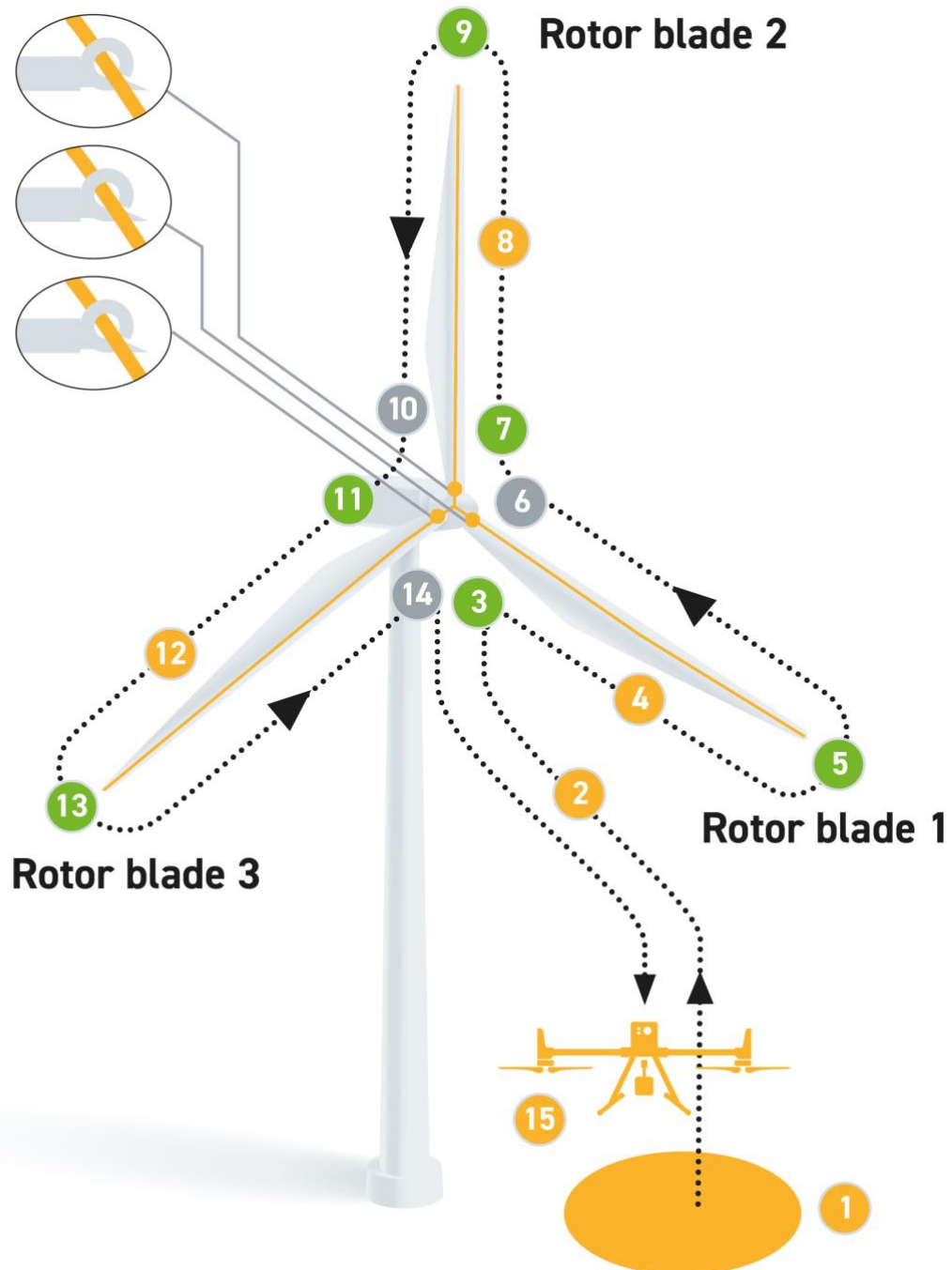


Figure 4: Schematic illustration of the inspection flight.

6.1. Using the TOPseven Signal Generator

Follow these step-by-step instructions to operate the TOPseven Signal Generator effectively:

1. Positioning:

- Place the TOPseven Signal Generator at the base/root of the wind turbine blade, ensuring the clamp with the coil is aligned with the Lightning Protection System (LPS) conductor.
- Use the clamp to fix and center the LPS cable properly in the center of the coil by hand. By hand means to pull/push so tightly that considerable force is applied but without pushing in the opposite direction, using any form of extension and/or support. Positioning is crucial for optimal induction of the AC current into the conductor for accurate measurements.

2. Power On:

- Press once the power button located on the back of the TOPseven Signal Generator.



The indicator will illuminate to show that the TOPseven Signal Generator is powered on and operational.

- Power On does **NOT** mean that the coil is already injecting an AC current, but that the TOPseven Signal Generator is powered up and waiting for the encrypted command from the TOPseven Field Sensor to inject the AC current.



NOTE

Note: the procedure for “Positioning” and “Power On” may vary due to wind turbine circumstances.

3. Monitoring during Inspection Flight:

- Monitor the operational status of the TOPseven Signal Generator using the indicator (during “Power On” and “Power Off”) in the TOPseven Pilot App.

4. Power Off:

- Press the power button to power off the TOPseven Signal Generator when the measurement session is complete.

- Ensure the unit is turned off (indicator off) to conserve battery life for future use.

6.2. Using the TOPseven Field Sensor

Step-by-step instructions for the operation of the TOPseven Field Sensor:

1. Attachment:

- Take the TOPseven Field Sensor carefully out of the case.
- Remove the gimbal protection cover and store properly.
- Attach the TOPseven Field Sensor securely to the drone's payload attachment system.
- Ensure the sensor is properly secured and functional using the pre-flight check in the TOPseven Pilot App.

2. Measurement Process:

- The measurement process is undertaken automatically and controlled by the TOPseven Pilot App following the above-mentioned sequence for the rotor blades.
- The TOPseven Field Sensor captures the near field signal strength data as the drone moves along the wind turbine blades.

3. Data Collection:

- Monitor the real-time data collected by the TOPseven Field Sensor forwarded to the TOPseven Pilot App.
- Ensure all required measurements are completed as per the inspection plan.

4. Detach and Store:

- Properly disconnect the TOPseven Field Sensor from the drone's payload system to avoid any damage during storage or transportation.
- Attach the gimbal protection cover and store securely in the case.

6.3. Charging the Devices

Using the TOPseven Charging Case:

1. Charging Preparation:

- Place the TOPseven Signal Generators and TOPseven Field Sensor in the charging case after use.
- Ensure all components are securely placed in their designated slots to prevent movement during charging of the TOPseven Signal Generators.

2. Connect Charger:

- Connect the USB-C charger to the charging case's power input port.



NOTE

Note: The charger can only be connected if the case is open.

Ensure the charger is securely connected to a suitable power source with the correct voltage rating.

3. Charging Indicators:

- Monitor the charge status using the LED indicator on the charging case for the respective slot.
- Each component's indicator (LED panel with percentage) will illuminate to show the battery charge status as a percentage when the button is pressed.

4. Completion:

- Allow sufficient time for charging until all components indicate a full charge status.
- Disconnect the charger from the charging case and leave the fully charged components for storage / transportation or remove immediate use.

6.4. Indicators and Controls

- **LPS Signal Generator Power Indicator:** Indicates whether the unit is powered on (e.g., blue LED if on, no indication if off).
- The TOPseven Field Sensor is controlled and monitored via the TOPseven Pilot App.

7. Maintenance & Care

7.1. Cleaning Instructions

Follow this cleaning procedure to maintain optimal performance and longevity of the TOPseven LPS Inspection Set components:

1. External Surfaces:

- Use a soft, dry cloth to wipe down the external surfaces of the TOPseven Signal Generators and TOPseven Field Sensor.
- Avoid using harsh chemicals or abrasive materials that could damage the casing or electronic components.
 1. **Avoid Harsh Chemicals:** Do not use harsh chemicals, such as bleach or ammonia-based cleaners, or abrasive materials that could damage the casing or electronic components.
 2. **Removing Grease:** For removing grease or oil, use a mild detergent or a cleaner specifically recommended for electronic devices. Apply the cleaner to a soft cloth, not directly to the equipment, and gently wipe the affected areas.
 3. **Approved Cleaners:** It is recommended to use isopropyl alcohol (70% concentration) for cleaning the surfaces of electronic components. Ensure the equipment is powered off and unplugged before cleaning.
 4. **Moisture Precautions:** Avoid excessive moisture during cleaning. Ensure no liquid enters the openings in the device to prevent short circuits or damage.

2. Drone Attachment Points:

- Ensure the drone's attachment points for the TOPseven Field Sensor are free from dirt or obstructions.
- Periodically inspect and clean these points to maintain secure attachment during operation.

3. Charging Case:

- Wipe the charging case with a dry cloth to remove dust or dirt.

- Keep the charging ports clean and free from dirt to ensure proper charging functionality.

4. Frequency of Cleaning:

- Perform cleaning as needed or after each use to prevent a buildup of dirt or contaminants.
- Store the components in a clean, dry environment when not in use to minimize exposure to dust or moisture.

7.2. Battery Replacement

If a battery in TOPseven LPS Inspection Set components requires replacement:



WARNING

The TOPseven Signal Generators are powered by rechargeable batteries and charged by the TOPseven Charging Case, which is also the transport case.

Contact TOPseven Customer Support for battery replacement. **Do not open any device.**

7.3. Troubleshooting

For common issues encountered with the TOPseven LPS Inspection Set, refer to the following troubleshooting tips:

1. No Power or Failure to Start:

- Check battery levels in the TOPseven Signal Generators and connection to the drone of the TOPseven Field Sensor.
- Ensure batteries are fully charged and power sources properly connected.
- Verify power switches are in the correct position and operational.

2. No Induction:

- The TOPseven Signal Generator is turned on as expected by the TOPseven Field Sensor, but no signal is induced into the LPS cable. This situation would result in an indication in the TOPseven Pilot App.

- If the indication in the TOPseven Pilot App is ok, then the TOPseven Signal Generator is probably not properly installed/mounted/connected to the LPS cable in the wind turbine. Make sure the LPS for the rotor blade is properly grounded and there are no ground loops.

3. Data Transmission Problems:

- Check for interference or environmental factors affecting signal transmission.
- Monitor data logs or indicators for errors and review system settings for optimal performance.

7.4. Software/Firmware Updates

To update the software or firmware in the TOPseven LPS Inspection Set:

1. Download Updates:

- Visit the TOPseven official website or contact Customer Support for the latest software/firmware updates.
- Download the update files and instructions provided by TOPseven.

2. Installation Process:

- Follow the installation instructions to transfer the update files to the device.
- Undertake the update process as instructed by the software/firmware update tool.

3. Verification:

- After installation, verify for successful update by checking system information or version numbers.
- Ensure all components are functioning correctly and that any new features or improvements are utilized effectively.

Regular maintenance, proper cleaning, and timely updates ensure the TOPseven Hardware remains reliable and efficient for wind turbine lightning protection system inspections.

8. Technical Specifications

8.1. TOPseven Signal Generator

General	Details
Model Name	TSLPS22-SG
FCC ID	2BNO9TSLPS22-SG
Keyboard and display	On/Off button for one-button startup with LED indicator
Dimensions (L × W × D) (Approx.)	27 cm x 7 cm x 5.5 cm
Weight (Approx.)	550 g
Material	PA12-HP Nylon (Casing)
Operating Frequency	13.565 MHz ± 1 kHz
Maximum Rated Output Power	-34.0 dBm EIRP (average)
Signal Form	Sine wave

Environmental Conditions

Temperature (Operating / Storage)	-10 °C to +50 °C / -20 °C to +50 °C
Humidity	80%
Dust and Water	IP44

Power

Internal	1800 mAh internal Li-Ion Battery (3S, 11.1 V) with protection
External	See TOPseven Charging Case
Power Consumption	<12 W

Communication and Data

Storage

Transmission Protocol	LoRa (Physical Layer Protocol)
Operating Frequency Range	915 MHz
Maximum Rated Output Power	+13.0 dBm EIRP (average)
Data Format	Proprietary data format over LoRa

8.2. TOPseven Field Sensor

General		Details
Model Name		TSLPS22-FS
Drones Supported		DJI M300 / M350 RTK (other drones on request)
Gimbal		DJI X-Port
Mounting		Removable
Operating Range		Pitch +30° to - 120°, Yaw: +320° to -320°
Angular Accuracy		± 1°
Dimensions (L × W × D) (Approx.)		13.35 cm x 8 cm x 11.5 cm (w/o gimbal)
Weight (Approx. – total)		670 g (with gimbal)
Material		PA12-HP Nylon (Casing)
Signal Measurement		Near field signal strength
Sampling Rate		256 kHz

Laser Range Finder	
Wavelength – Safety	850 nm – Class 1 (EN60825)
Frame Rate	Up to 100 Hz
Range (Accuracy)	Up to 40 m (± 1% of distance)

Camera	
Resolution	1080p
Frame Rate	30 fps
Field of View	142°

Environmental Conditions	
Temperature (Operating / Storage)	-10 °C to +50 °C / -20 °C to +50 °C
Humidity	80%
Dust and Water	IP44

Power

Internal	Only external – no battery
External	External 13 V power supply from drone (~5 W) internal 5 V ~ 1 A
Power Consumption	Up to 5 W

Communication and Data

Storage

Transmission Protocol	LoRa (Physical Layer Protocol)
Operating Frequency	915 MHz
Maximum Rated Output Power	+13.0 dBm EIRP (average)
Processing Board	Single-board computer
SD Card	Min. 32 GB and up to 128 GB, at least 50 MB/s read/write speed

8.3. TOPseven Charging Case

General		Details	
Dimensions (L × W × D) (Approx.)		55 cm x 41 cm x 22 cm	
Weight (with contents) (Approx.)		5.3 kg	
Weight (with all components) (Approx.)		9.8 kg	
Material		Polypropylene-Copolymer (Casing), Foam Inlay	
Environmental Conditions			
Temperature (Operating / Storage)		0 °C to +50 °C / -20 °C to +50 °C	
Humidity		80%	
Dust and Water (closed)		IP67	
Power			
Power Supply		Lenovo USB-C Charger 4X20M26272, 65 W	
Compatibility		USB-C Power delivery (USB-PD) Required minimum profiles: 3 A@20 V, 3 A@15 V	
Power Consumption		Max. 40 W	

8.4. Compliance Statements

Statements for the following Models and FCC IDs

Model Name	TSLPS22-SG
FCC ID	2BNO9TSLPS22-SG

FCC Caution Statement

According to FCC 15.21, users are cautioned that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Compliance Statement (for small devices)

This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment and meets the FCC radio frequency (RF) Exposure Guidelines. This equipment should be installed and operated by keeping the radiator at least 5 m or more away from a person's body (leave the nacelle during inspection). In North America the band with 902 – 928 MHz (ISM-Band Region 2) is used.

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.
2. This device must accept any interference received, including interference that may cause undesired operation.

This device complies with Part 15 of the FCC Rules. Operation is subject to the conditions that this device does not cause harmful interference and that it must accept any interference received, including interference that may cause undesired operation.

FCC Compliance for Devices under FCC 15.225

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.

Please note that the device is designed to operate within the frequency range specified under FCC 15.225, ensuring it complies with the necessary regulatory requirements for safe and lawful operation.

For more detailed information, users are advised to refer to the User Manual or contact TOPseven's Customer Support.

For questions regarding your product or for TOPseven Customer Support contact support@TOPseven.com.

Supplier's Declaration of Conformity

Product Name: TOPseven LPS Inspection Set

Model: TSLPS22

Manufacturer's Name: TOP seven GmbH & Co. KG

Manufacturer's Address: Württemberger Str. 13, 26723 Emden, Germany

FCC Responsible Party: Testing Partner LLC

FCC Responsible Party Address: 18200 SR 306, Chagrin Falls, OH 44023 U.S.A.

FCC Responsible Party Telephone Number: +1-862 243 2329

FCC Responsible Party E-Mail Address: info@testingpartners.com

9. Disposal Information

9.1. Environmentally Safe Disposal

While disposing of TOPseven LPS Inspection Set components, follow these guidelines to ensure environmentally safe practices:

1. **Contact Support:** For return or disposal of the system contact our Support, TOPseven will ensure correct disposal according to regulations. Do not dispose of yourself.
2. **Packaging Materials:** Recycle packaging materials whenever possible. Dispose of packaging in accordance with local recycling guidelines.

9.2. Warranty & Liability Information

9.2.1. Warranty & Liability Terms

TOPseven provides a limited warranty for the LPS Inspection Set components. The warranty terms typically cover defects in materials and workmanship in normal use for a specified period from the date of delivery. Details of the warranty terms and conditions as well as liability are specified in the individual contracts between TOPseven and a customer.



Under any circumstances: Do not open any device since the device's internal components are protected by design to prevent tampering or unauthorized access. Attempting to access these components would compromise contractual agreements of TOPseven customers. As detailed in TOPseven's agreement terms, TOPseven imposes strict contractual obligations on TOPseven customers to refrain from tampering with or reverse-engineering the device, including contractual penalties for breaking seals or opening enclosures. Contractual penalties are enforced for breaking seals or exposing internal components, ensuring compliance with safety and intellectual property protections.

9.2.2. How to Claim under the Warranty

If you believe your TOPseven LPS Inspection Set component is defective and eligible for a claim under the warranty, follow these steps:

1. **Contact Support:** Reach out to TOPseven Customer Support.
2. **Describe the Issue:** Explain the issue you are experiencing with the product and provide any relevant details.
3. **Follow Instructions:** Follow the instructions provided by TOPseven Customer Support regarding troubleshooting steps, returning the product, or initiating a claim under the warranty.
4. **Repair or Replacement:** If the product is determined to be eligible for a claim under the warranty, TOPseven will repair or replace the defective component according to the terms of the warranty.

By adhering to these disposal guidelines and understanding the warranty terms, you contribute to environmental protection and ensure the longevity and reliability of your TOPseven LPS Inspection Set.

10. Trademarks/Licenses

- USB Type-C[®] and USB-C[®] are registered trademarks of USB Implementers Forum.
- QR Code is a trademark of Denso Wave Inc.
- The LoRa trademark is used as an equivalent to the LoRaWAN[®] trademark.
- The terms HDMI, HDMI High-Definition Multimedia Interface, and the HDMI Logo are trademarks or registered trademarks of HDMI Licensing Administrator, Inc.
- In addition, the system and product names used in this manual are, in general, trademarks or registered trademarks of their respective developers or manufacturers. However, the [™] or [®] marks may not be used in all cases in this manual.
- **IMPORTANT – Read the End User Software License Agreement before using the product.** Using the product indicates your

acceptance of the End User Software License Agreement. The software license agreement between you and TOPseven is handled in your respective contract.

11. Disclaimer

Read carefully this entire document and observe all safe and lawful practices/attend training provided by TOPseven before using this product for the first time. Failure to read and follow instructions and warnings may result in serious injury to yourself or others, damage to your TOPseven product, or damage to other objects in the vicinity. By using this product, you hereby signify that you have read this document carefully and understand and agree to abide by all terms and conditions of this document as well as all relevant documents related to this product. You agree that you are solely responsible for your own conduct while using this product and for any consequences thereof. TOPseven accepts no liability for damage, injury, or any legal responsibility incurred directly or indirectly from the use of this product.

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12. Appendices

12.1. Glossary of Terms

- **LPS (Lightning Protection System):** A system designed to protect wind turbines from lightning strikes by safely conducting the electrical current to the ground.
- **LoRa (Long Range):** Low-power wide-area network (LPWAN) technology used for long-range communication between devices.
- **Coil:** A type of component used in electromagnetic applications for generating specific magnetic fields.
- **Processing Unit:** A single-board computer used for processing signals and data in the TOPseven Field Sensor.

12.2. Frequently Asked Questions (FAQ)

1. What is the purpose of the TOPseven LPS Inspection Set?

The TOPseven LPS Inspection Set is used for non-contact inspection of lightning protection systems on wind turbines using drone-based technology.

2. How do I charge the TOPseven Signal Generator?

Use the USB-C charger provided to charge the TOPseven Signal Generators in the charging box slots. Connect the charger to a power source and the charging port in the casing. Make sure that the TOPseven Signal Generators are properly connected to the connector. Check the connection by pressing the button at the respective charging slot.

3. What should I do if the TOPseven Signal Generator does not power on?

Check the charge status of the battery and ensure it is adequately charged. If the problem persists, contact TOPseven Customer Support for assistance.

4. Can the TOPseven LPS Inspection Set operate in adverse weather conditions?

The system is designed to operate in varying weather conditions, but it is essential to follow safety guidelines and avoid extreme weather that could endanger equipment or personnel. Our system boasts weather-independent operation, allowing inspections to be conducted in varying weather conditions, including rain, fog, clouds, and winds up to 15 m/s. However, we do not recommend operating the drone in adverse weather conditions such as high winds (>15 m/s), heavy rain, dense fog, snow or lightning. It is recommended you follow these restrictions to prevent malfunctions in the drone's (e.g. DJI) obstacle avoidance sensors.

5. How often should I perform maintenance on the TOPseven LPS Inspection Set?

Regular maintenance is recommended to ensure optimal performance. Refer to local regulations for detailed instructions.

6. Can you provide evidence of superior performance compared to competitors?

Yes, TOPseven's technology has been validated by TÜV Süd and insurance companies, demonstrating its reliability and accuracy compared to the traditional rope access method for an ohmic resistance measurement. TOPseven has case studies showcasing our system's ability to localize multiple defects accurately and provide detailed reports in a fraction of the time of competitors. The flexibility of TOPseven's technology allows operators to adjust inspection parameters based on weather conditions and client requirements. TOPseven experts are available for detailed technical discussions. Please contact TOPseven Customer Support.

7. How does your solution address SMT connectivity in turbine blades?

TOPseven has extensive documentation of SMT connectivity simulations and experiments including field tests and customer success stories. The

TOPseven system is designed to accommodate SMT connections through a single cable, facilitating efficient and effective inspections.

13. Support

If you have any suggestions, questions or requests, please contact your TOPseven contact person at any time or visit our TOPseven [Customer Center](#).

Tel.: +49 89 515550-366

E-Mail: support@TOPseven.com

About TOPseven

TOPseven – MAKING DRONES SMARTER.

TOPseven is a developer of software and technology with a focus on drone technology, cloud computing and artificial intelligence. With an international team of experts, TOPseven develops AI-based navigation and analysis software as well as special hardware in the areas of sensors and drones.

For the future TOPseven has set itself the task of making it possible to inspect, regularly and completely, even difficult to access infrastructure so that damage can be detected at an early stage, the consequences of the damage minimized and service life increased.

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Register court: Amtsgericht Munich HRA 112608

General partner: TOP seven Management GmbH with registered office in Potsdam, registered in the Commercial Register of the Amtsgericht Potsdam under HRB 34027 P, represented by its managing directors Heiner Röger and Knud Ezra Rissel.

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