INTERSOFT ELECTRONICS

SkyRF

Drone-based CNS measurements

Introduction to SkyRF®

Intersoft Electronics and Skyguide have developed SkyRF®, the drone-based CNS measurement service that addresses the challenges of CNS performance analysis and certification.

SkyRF® can measure CNS system parameters in a single 10-minute flight, and can even combine the measurement of different CNS, e.g. ILS and DME. Traditional test flights cannot compete with the repeatability of SkyRF®'s pre-programmed trajectories. The drone complements existing ground measurements by reducing ground clutter as it flies at altitude.

As a result, the correlation between SkyRF® (i.e. ground measurements) and test flights is very good, and test flights can be reduced to one campaign per year, according to ICAO 8071 directives. This reduces CO_2 emissions and noise pollution by 50%.

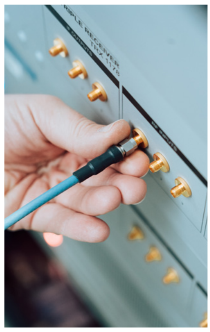
This publication explains how drone-based measurements fit in the maintenance of CNS, and exactly how SkyRF® delivers this positive environmental impact and what the operational and financial benefits are for air navigation service providers and military CNS users.

Domien De Ruyck,
Managing Director Intersoft Services

SkyRF® supports different drone platforms to ensure operability at a wide range of locations and countries. The Real-Time Kinematic (RTK) drones DJI M350, IF800 and IF1200A enhance the precision of GPS/GNSS position data to centimeter-level accuracy.
SkyRF® also supports blue listed variants compliant to the USA National Defense Authorization Act.

PREPARE

- Flight path definition
- CNS systems specifications

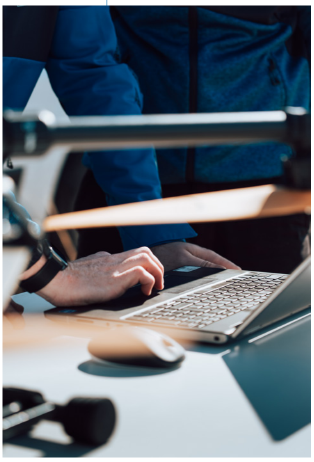


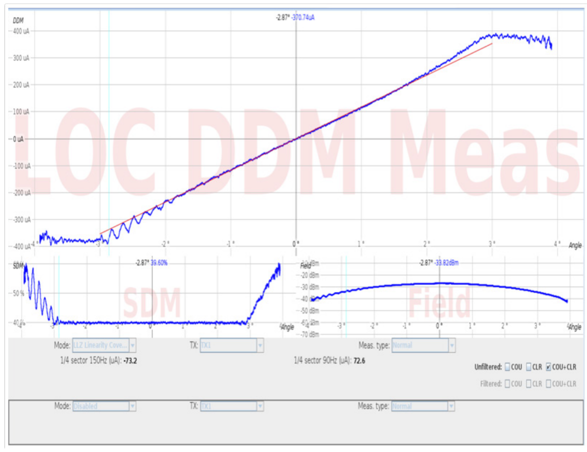
MEASURE

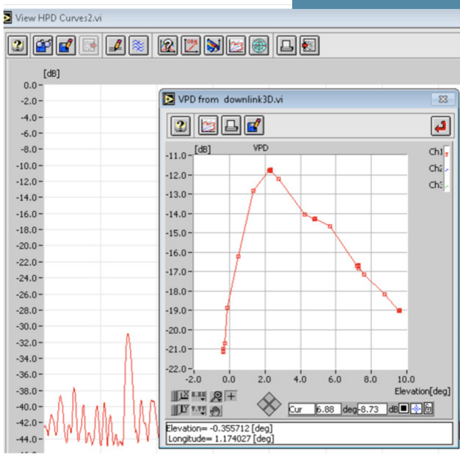
- **Live monitoring through direct link or over cellular network** (encrypted communication over VPN network)
- **Automatic flights** (Pilot is present for safety reasons)
- **Time synchronised recording of measured system signals**
- **Periodicity is based on customer needs** (e.g. monthly ILS measurements in Skyguide for preventive maintenance)

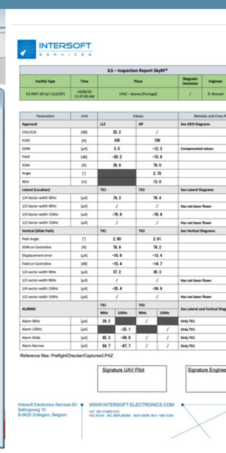
ANALYZE

- Live monitoring, so immediate analysis on measured results
- Dedicated software for ILS/DME and VOR/DME analysis
- Surveillance related applications based on RASS®, the industry standard radar measurement tools
- Automatic Reporting









SOLUTION

Intersoft Services is an experienced CNS services provider. Next to the measurement services, Intersoft offers planning, integration, installation, maintenance, calibration and repair services on ILS, radar and meteo systems.

Introduction to ILS Measurement

The Instrumented Landing System (ILS) is a critical component of airport navigation infrastructure, and its performance must be measured regularly to ensure the safety and precision of aircraft landings. Frequent measurement is essential because even minor deviations in signal alignment or strength can compromise landing accuracy, especially under low-visibility conditions.

ILS measurements are typically conducted using specialized flight inspection aircraft or ground-based test equipment. These systems evaluate parameters such as localizer and glide slope alignment, signal strength, modulation depth, and coverage. Measurements are performed both during commissioning and at regular intervals as part of ongoing maintenance and regulatory compliance.

However, measuring ILS performance presents several challenges:

- **Aircraft dynamics** during flight inspection introduce variability in measurements.
- **High precision requirements** demand advanced calibration and synchronization of equipment.
- **Operational constraints** at busy airports can limit the availability of measurement windows.

Drone-based ILS measurement is emerging as a transformative alternative that addresses many of these limitations. By flying pre-programmed, repeatable trajectories with high positional accuracy, SkyRF® can collect detailed signal data with minimal operational impact and significantly lower cost. The ability to operate in tighter airspace and closer to ground installations also enables more granular diagnostics of localizer and glide slope performance.

The shared location, compatible signal types, and overlapping flight paths make Distance Measurement Equipment (DME) a natural addition to drone-based ILS measurement campaigns.

For a complete ILS/DME assessment, the SkyRF® drone flies three trajectories consequently:

- Mini-Orbit: Localizer (LLZ)/DME measurement
- Vertical: Glide Path (GP)/DME profile measurement
- Mini-Approach: LLZ, GP and DME simultaneous measurement

Course, clearance, frequency and absolute power are measured through AM modulation of the 90/150 Hz signals. The difference in depth of modulation (DDM) is an indication of the exact position relative to the landing strip.

Measurement data can be streamed, enabling live monitoring of all parameters like GP angle, sector widths and DME distance. Other parameters that are visualized by the ILS Preflight Checker software are LLZ displacement error, course/clearance ratio and threshold crossing height in normal and alarm conditions. The DDM is also plotted versus the azimuth angle.

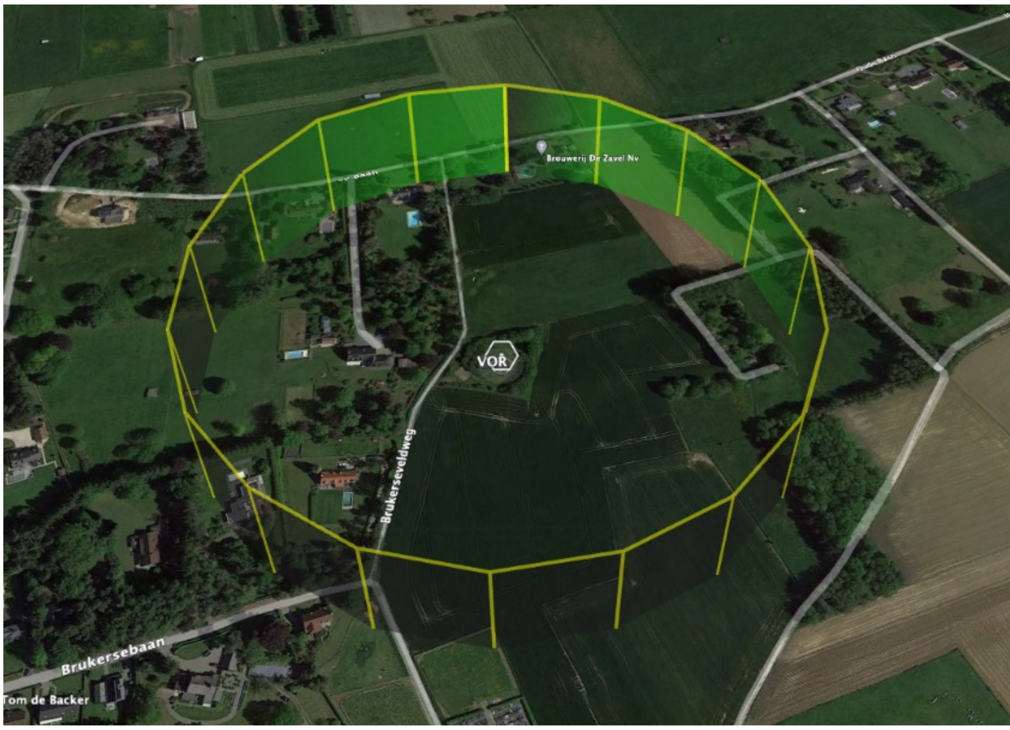
- ☑ **ILS/DME measurement in a single 15 minutes drone flight**
- ☑ **50% less test flights, 50% less CO2 emissions no noise disturbance**
- ☑ **No runway downtimes**
- ☑ **High repeatability and accuracy**
- ☑ **Low cost**

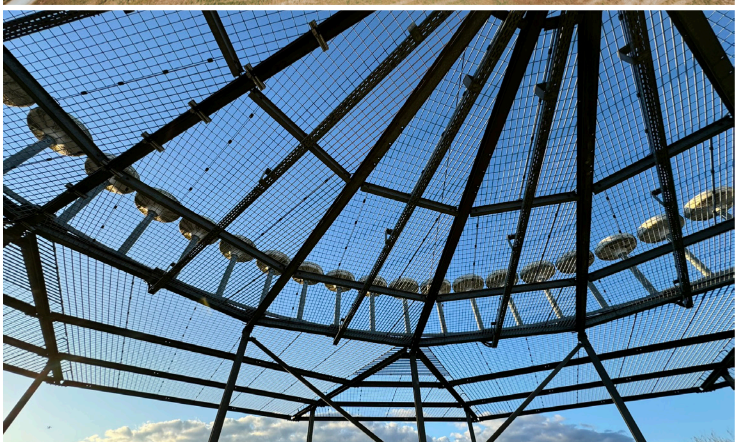
Introduction to DME, VOR and TACAN Measurement

Accurate performance of Distance Measuring Equipment (DME), VHF Omnidirectional Range (VOR), and Tactical Air Navigation (TACAN) systems is essential for safe and reliable en-route and terminal navigation.

Traditionally, measurements are performed using flight inspection aircraft, which assess signal strength, bearing accuracy, and range precision. However, this method is costly and operationally disruptive.

Drone-based measurement offers a modern alternative, enabling cost-effective, repeatable, and high-resolution data collection. The SkyRF® drone can fly precise paths to evaluate signal characteristics with minimal impact on airport or airspace operations. The ability to measure DME and VOR simultaneously, and even assess TACAN performance in military contexts, makes SkyRF® a versatile tool for both civil and defense applications.





For a complete VOR/DME measurement, the SkyRF® drone flies two trajectories consequently:

- Radial: range measurement and calculated error
- Orbits: azimuth/bearing measurement

To analyze performance of the VOR, the same trajectories as for DME are used. That allows to measure the azimuth error, FM deviation, RF Level and the 30 Hz and 9960 Hz modulation depths versus azimuth angle and distance.

Trajectories are designed in a way that allows deep analysis of the cone of silence. Measurement data can be streamed, enabling live monitoring of all parameters such as azimuth error, FM deviation, RF Level and modulation depths.

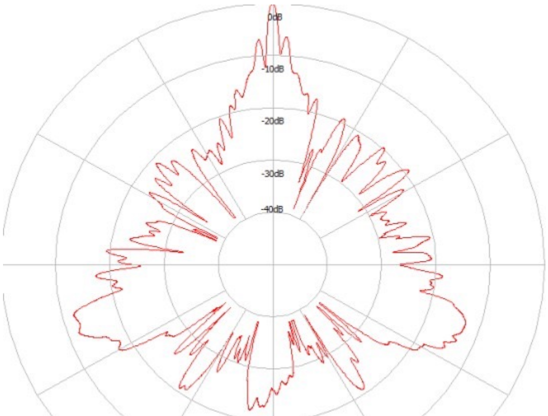
SkyRF® can service the military TACAN stations to the same extend and accuracy (or better) as the civil VOR/DME navaids.

- **Measure air-to-ground and ground-to-air frequencies in a 15 minutes drone flight**
- **Radial and orbital alignment and signal deviation verification**
- **Horizontal and vertical polarization measurements in a single drone flight**
- **50% less test flights, 50% less CO2 emissions no noise disturbance**
- **High repeatability and accuracy**
- **Low cost**

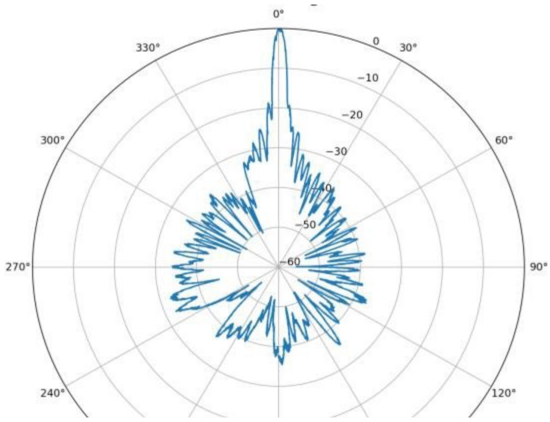
Introduction to measuring antenna radiation patterns

The vertical and horizontal polar diagrams (VPD and HPD) of a radar antenna—also known as antenna radiation patterns—are measured to understand how the antenna radiates energy in different directions. These diagrams are crucial for verifying that the antenna meets design specifications and performs correctly in operational environments.

SkyRF® measures antenna radiation patterns of PSR, SSR/IFF or combined systems in a single 15-minute flight. Performing these drone-based measurements at altitude overcomes the limitations of ground measurements and eliminates the need for test flights. SkyRF® extends integrates with the RASS® portfolio of measurement equipment and tools for exhaustive radar analysis and support. SkyRF® data recordings convert directly into the RASS® file format and can as such be used for detailed HPD and OTD (Out of Tolerance Detection) analysis.



HPD ground measurement (negative elevation angle) with urban interference



HPD of the same radar with SkyRF (positive elevation) away from obstructions

Buildings, terrain obstructions, and negative measurement angles can cause distorted HPD graphs. Therefore, it is crucial that measurements are taken in the Far Field, at (multiple) positive elevation angles and different ranges and azimuths. SkyRF® achieves this in a minimal amount of time with great flexibility for PSR and SSR/IFF systems.

VPD information can be measured while flying vertically relative to the radar. SkyRF® compensates for slant range and terrain deviations to calculate the maximum power for every elevation angle in relation to the radar system. The results are displayed in a live feed from the flying platform.

In addition to the transmit VPD pattern, the receive VPD beams (and beam combining) can also be measured using CW signals that are geographically referenced by SkyRF®'s differential GPS, inertial and pressure computed altitude.

- **HPD measurements at multiple ranges, azimuths and elevation angles in the same flight**
- **VPD from cone of silence to negative elevation angles with Slant range correction and full transmitter health check**
- **No downtime for uplink measurements**
- **Live feed for real time data monitoring**
- **Downlink receive VPD beam measurement and beam combining**

Similar to the HPD/VPD measurements for radar, SkyRF® can measure those diagrams also for radio systems. That entails all VHF, UHF, L, S and C band ground-air-ground (GAG) communications systems.

- Relative and absolute power density measurements
- HPD, VPD and coverage analysis
- Spectrum analysis and direction finding

Radar Target Generation

With SkyRF®, Radar Targets can be simulated for Secondary Radar in Modes 1, 2, 3/A, and C, covering both Transponder and Interrogator functions. Additionally, a transponder can be mounted to support Mode S and Mode 5 (AIMS certified).

Sensor alignment

Many airfields with primary radar installations use active reflectors to check the geographical alignment of the PSR video with the touchdown points, runway crossing points, etc. The active reflector (also known as a stationary target) must produce a Doppler shift such that the stationary target is not filtered out as clutter but passes through the Moving Target Indication (MTI) / Moving Target Detection (MTD) processor and is presented on the radar screen of the Air Traffic Controller. SkyRF® provides such a dynamic 360° target with the following configurable parameters:

- Doppler
- RCS
- Distance

Missile generation – Testing of Combat Management Systems

The testing of Combat Management Systems such as Counter Battery and Missile Defense radars is a complex and costly matter. The use of ammunition and the availability of safe test grounds are expensive needs for conventional field testing.

SkyRF® Target Generation capabilities make this testing way more achievable. It can simulate a target – with predefined RCS, Doppler and velocity – following a ballistic trajectory and send this signal out on RF level. The detection of the Counter Battery or Missile Defense system is then compared to the generated scenario for evaluation.

PAPI Calibration reinvented

Precision Approach Path Indicators (PAPI) are critical for guiding pilots during final approach. Accurate calibration ensures optimal glide slope visibility and enhances runway safety, especially in low-visibility conditions.

Traditional PAPI calibration methods are time-consuming, costly, and often disruptive. Drone-based solutions offer a faster, safer, and more precise alternative.

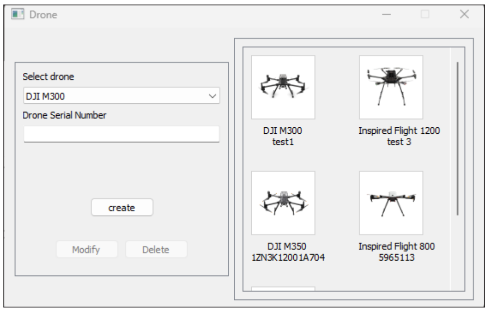
SkyRF® calibrates your PAPI systems faster and more accurate compared to traditional test flights. The SkyRF® drone flies a preprogrammed trajectory which is highly repeatable and executed in less than fifteen minutes. During test, SkyRF® measures PAPI system angle, transition angles for each unit, angular coverage, horizontality, symmetry and relative brightness.

- **High Accuracy:**
  Real-time data collection with centimeter-level GPS precision.
- **Rapid Deployment:**
  Setup and calibration completed in under half an hour.
- **Non-Disruptive:**
  No need to close runways or interrupt airport operations.
- **Automated Reporting:**
  Instant generation of calibration reports for compliance and auditing.

1

Flight planning

The drone is programmed to fly the standard approach path.



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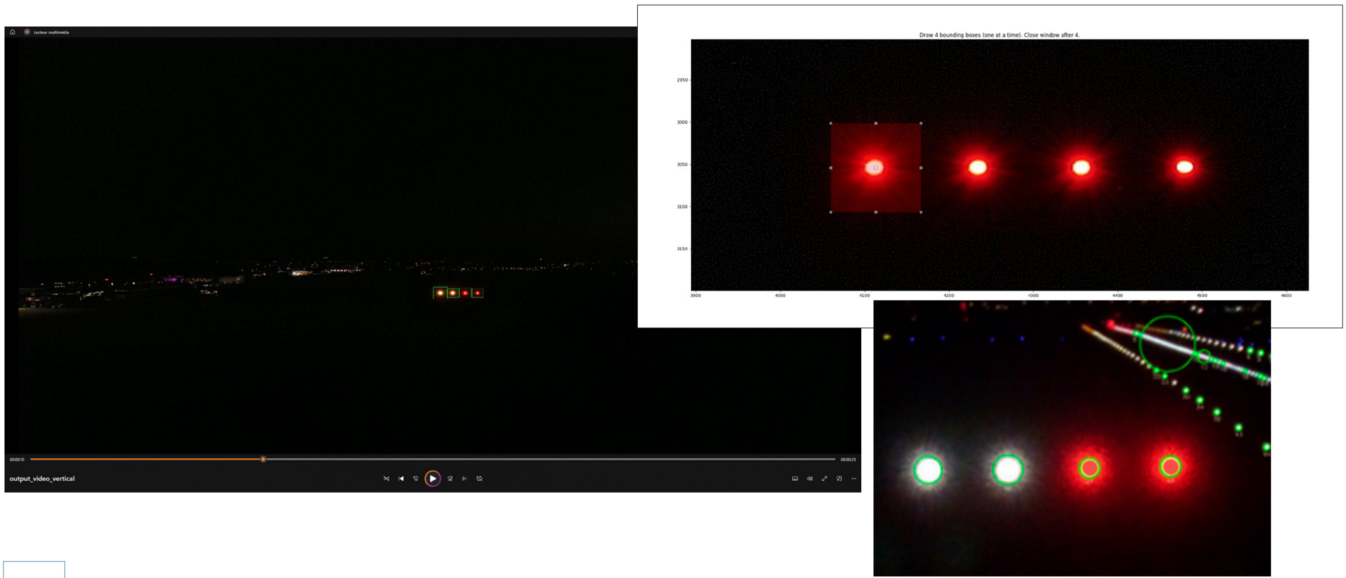
Data Capture

High-resolution sensors record PAPI light angles and intensities.



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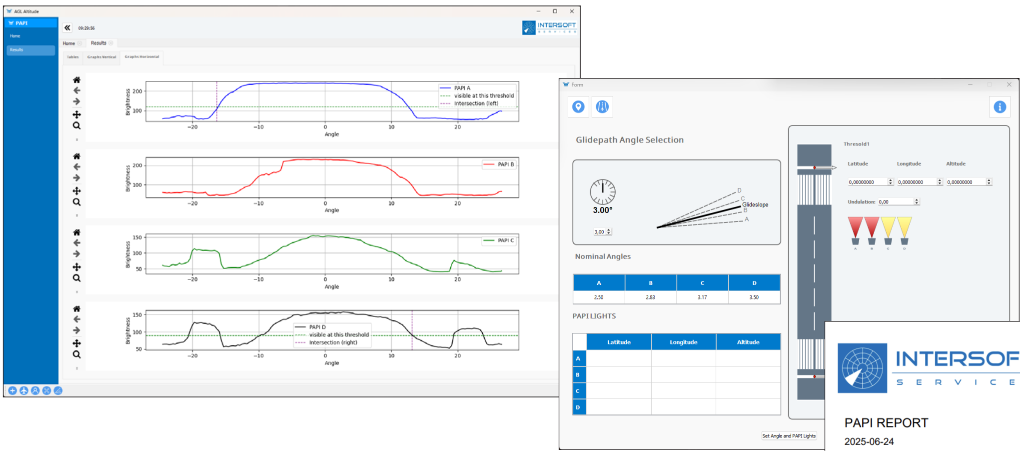
Analysis

Software compares actual light beam positions with ICAO/FAA standards.



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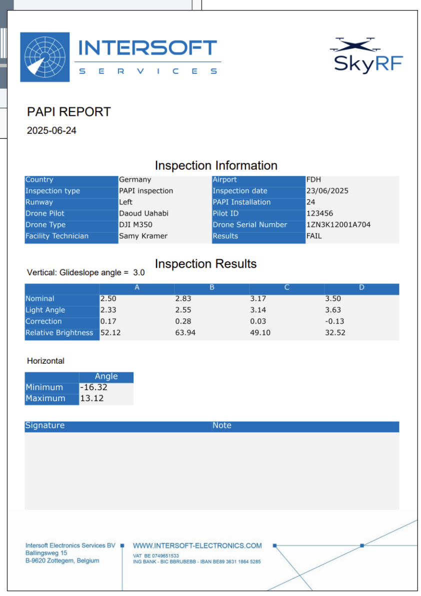
Reporting

A detailed calibration report is generated and delivered on-site.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SkyRF

PAPI REPORT

2025-06-24

Inspection Information

Country	Germany	Airport	FDH
Inspection type	PAPI inspection	Inspection date	23/06/2025
Runway	Left	PAPI Installation	24
Drone Pilot	Daoud Uahabi	Pilot ID	123456
Drone Type	DJI M350	Drone Serial Number	1ZN3K12001A704
Facility Technician	Samy Kramer	Results	FAIL

Inspection Results

Vertical: Glideslope angle = 3.0

	A	B	C	D
Nominal	2.50	2.83	3.17	3.50
Light Angle	2.33	2.55	3.14	3.63
Correction	0.17	0.28	0.03	-0.13
Relative Brightness	52.12	63.94	49.10	32.52

Horizontal

	Angle
Minimum	-16.32
Maximum	13.12

Signature	Note

Intersoft Electronics Services BV
Ballingsweg 15
B-9620 Zottegem, Belgium

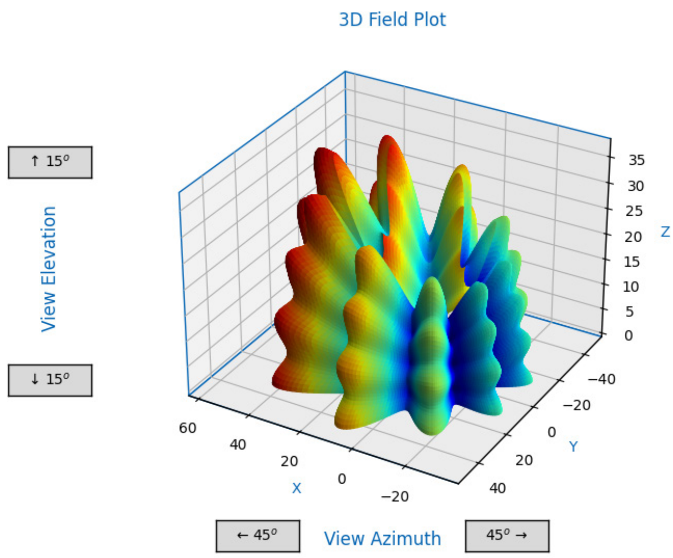
WWW.INTERSOFT-ELECTRONICS.COM
VAT BE 0749651533
ING BANK - BIC BBRUBEBB - IBAN BE89 3631 1864 5285

Classic image processing techniques utilizing light detection are employed. Pictures are transformed into binary images, and subsequent filtering processes such as erosion and dilation are applied to easily detect light spots.

Drone-based Antenna measurements

Satellite networks are indispensable in many communication, navigation and surveillance (CNS) systems. Huge dish antennas at the ground stations integrate the satellites into complex networks involving fiber, wireless and mobile technologies. Optimal performance of satellite antennas is critical to deliver qualitative services. The CNS drone SkyRF® is the most cost effective measurement solution available for satellite antenna testing.

- Accurate antenna test and calibration
- Interferences control and reduction
- Visualize clutter effects
- Check antenna diagrams (VPD, HPD), both in up-link and in down-link
- Receive the signals transmitted by the ground antenna (any modulation) and show it in real time during the mission to the operator
- Record the transmitted signal, as received by the drone, for post-processing (also encrypted signals)
- Generate and transmit to ground antenna under test specific signals (modulation, power level) from specific positions



Naval CNS measurements

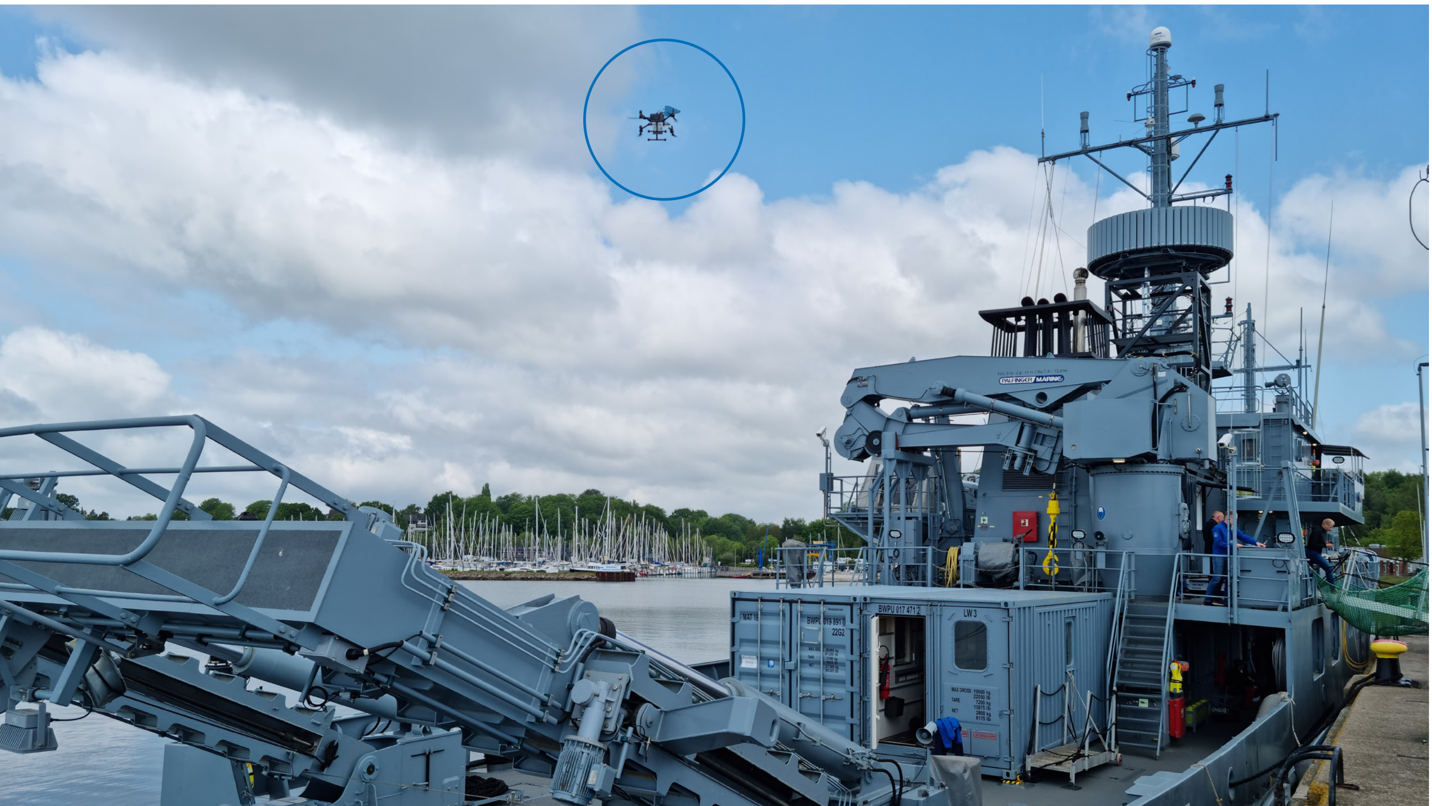
Thanks to its agility and compactness, the SkyRF® drone is extremely well suited for measurements on-board ships and naval vessels.

Cositing analysis

- To identify the effects due to the presence of the other installed equipment and the ship structure, SkyRF® flies a preprogrammed trajectory around the vessel and its telemetry antenna.
- The recorded measurements are compared to the antenna's test results from anechoic chamber measurements.
- The three channels transceiver on-board of the SkyRF® drone can also scan the spectrum, catching the interference and spurious signals as well.

Tracking test

- During this test, the SkyRF® drone can fly along a specific trajectory, transmitting the GPS signal to the ship in real-time.
- On-board, a C2 console will initiate the TX antenna to track the drone.
- In this way the antenna subsystem's tracking functionality can be tested without the need of an expensive flying target.



In summary,
with the SkyRF® CNS drone you win!

FINANCE	50% flight check aircraft cost reduction
REAL-TIME	Live Results
SAFETY AND CAPACITY	Less operational disturbance of air traffic
ENVIRONMENT	Less CO2 emission and noise disturbance
MATURITY	Operationally proven solution for more than 7 years
CNS	Measures signal in space for the complete CNS domain

SkyRF

Take CNS Measurements to the next level

NAVIGATION

ILS/DME	VOR/DME	PAPI

PSR and SSR UPLINK-DOWNLINK	L-IESA® UPLINK-DOWNLINK	NORA® UPLINK-DOWNLINK

SURVEILLANCE

SkyRF® CNS Receiver

Characteristics

General

Frequency Range	70MHz - 6GHz
Frequency Accuracy	< 1ppm
Carrier recovery	PLL
(De)Modulation	AM, FM, QAM, PAM, …
Maximum Input Power	10dBm
Minimum Input Power	-80dBm | with LNA: -100dBm
Maximum Output Power	20dBm (can be amplified if required)
ADC	2x12 bits
Dynamic range (single measurement setting)	72dB
Temperature range	-10 - 45°C
Power Supply	12 - 36V, max. 3A

ILS

ILS max output rate	300Hz
ILS measurement bandwidth	Tunable
AM Depth Standard Deviation (20%)	< 0.01%MI
Carrier modulation content - 2nd harmonic	< 0.1%
Ripple	< 0.02%

VOR

VOR max output rate	> 1kHz
VOR measurement bandwidth	Tunable
9960Hz deviation	< 1Hz
AM Depth Standard Deviation (30Hz - 30%)	< 0.01%MI
FM Depth Standard Deviation (30Hz - 30%)	< 0.1%MI
Bearing Standard Deviation	< 0.05°

DME

Pulse spacing error	<0.1µs
Interrogation pulse spacing	Adjustable
Decoding limits	Adjustable (default: 10-14µs / 28-32µs)
Accuracy	< 12m
Interrogation rate	> 100Hz (Adjustable)

ILS Marker Beacons

AM Depth Standard Deviation	< 0.01%MI

TACAN

Pulse spacing error	<0.1µs
Interrogation pulse spacing	Adjustable
Decoding limits	Adjustable (default: 10-14µs / 28-32µs)
Accuracy	< 12m
Interrogation rate	> 100Hz (Adjustable)
Bearing Standard Deviation	< 0.1°

PSR/SSR

Sample Frequency	4/8/16/32/64 MHz
SSR Interrogation Decoding	Available
Mode S Interrogation Analysis	Available
Mode 5 Pattern Recognition	Available

Compliant to

ICAO 8071	STANAG 3374	FAA 8200.1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marketing@intersoft-electronics.com

We make the sky safer