

Starlink Uplink Detection using AI technology

Introduction and concept

The rapid global proliferation of low-Earth orbit (LEO) satellite broadband services — led by SpaceX Starlink — has introduced a new class of RF emitter that poses unique challenges for spectrum monitoring, border security, and signals intelligence operations. Starlink user terminals transmit high-power, broadband uplink signals in the Ku-band (13.85 – 14.5 GHz), employing phased-array beam steering, frequency-division multiple access (FDMA), and dynamic carrier allocation. These characteristics make passive identification, classification, and geolocation of active terminals a technically demanding but operationally significant problem.



From a security and sovereignty perspective, Starlink terminals provide adversaries, smugglers, and hostile actors with highly resilient, high-bandwidth satellite connectivity that bypasses all terrestrial network controls. A single terminal can establish a full-duplex broadband link at any location with sky visibility — making the RF uplink signature the only externally observable indicator of active terminal operation.

The YOTASYS Y9827A Inception Spectrum Analyzer addresses this challenge directly. Using the Y9827A's broadband real-time spectrum analysis (RTSA) capability, CUDA-accelerated IQ signal processing on the embedded NVIDIA Jetson Orin NX, and the Y9800A CNN-LSTM signal intelligence platform, YOTASYS has demonstrated passive detection, waveform characterisation, and preliminary geolocation feasibility of Starlink terminal uplink emissions — from a standard compact horn antenna, without any cooperation from the terminal or the Starlink network.

This application note summarises the measurement approach, key findings, and the pathway to a production-grade Starlink terminal detection and geolocation capability on the Y9827A platform.

Highlights

- Passive Ku-band uplink detection from 13.95–14.55 GHz with compact horn antenna
- Boot-phase scan signature: distinctive ascending-frequency sweep detected at low antenna gain
- Active uplink characterisation: ~120 MHz SC-OFDM carrier, flat PSD, –57 dBm near-field peak
- Frequency-hopping tracking: 600 MHz wide-span RTSA captures hops across the full allocation
- IQ data acquisition at 50 MB/s (I16 format) for CNN classifier training on Y9800A platform
- CNN signal classification: STARLINK_SCAN and STARLINK_UPLINK as distinct signal classes
- TDOA geolocation feasibility: multi-receiver IQ capture with GPS 1PPS synchronisation
- Node-RED integration: scan-phase detector node and automated alert workflows

Applications and use cases

- **Border and perimeter security:** detection of illicit Starlink terminal activations near controlled zones, providing early warning of satellite-connected adversaries operating off-grid
- **Maritime domain awareness:** identification of vessels equipped with Starlink terminals transmitting in the Ku-band, complementing AIS and radar surveillance
- **Electronic Warfare (EW) support:** passive terminal detection without emitting any countermeasure signal; TDOA-based geolocation for targeting and direction finding
- **SIGINT collection:** waveform characterisation and traffic pattern analysis of Starlink uplink carriers for signals intelligence applications
- **Critical infrastructure protection:** monitoring of Ku-band spectrum around sensitive sites to detect unauthorised satellite uplink activity
- **Regulatory enforcement:** spectrum monitoring agencies detecting unlicensed or non-compliant Starlink terminal operation within national spectrum allocations

Product Y9827A Inception Spectrum Analyzer

The Y9827A Inception is a rack-mounted, full-spectrum RF monitoring instrument designed for continuous, unattended operation in demanding field and infrastructure environments. It is built on a stacked architecture that combines the proven RF front-end of the Anritsu MS27201A with YOTASYS Inception Technology™: an integrated NVIDIA Jetson Orin NX processor running Ubuntu Linux, Node-RED, ONNX inference libraries, and the full Y9800A software suite.



At the computational core sits the NVIDIA Jetson Orin NX GPU module — delivering 157 TOPS (INT8) of AI inference performance in a power-efficient, thermally optimised form factor. This brings cloud-class neural network processing directly to the field sensor, eliminating latency, bandwidth consumption, and the data security risks associated with remote server or cloud-based AI architectures. CNN inference, LSTM anomaly scoring, and TDOA cross-correlation all execute locally in under one millisecond per analysis cycle.

For Starlink uplink detection, the Y9827A is configured in RTSA mode with OPT-0124 IQ Signal Analysis active, providing:

- 600 MHz spectrum monitoring span covering the complete Ku-band uplink allocation (13.95–14.55 GHz) in a single sweep — essential for tracking a frequency-hopping terminal across all possible carrier positions
- Spectrogram capture with 200 ms sweep time and 10 kHz RBW, sufficient to resolve individual frequency hops and the characteristic boot-phase scan pattern
- IQ streaming at 50 MB/s in I16 format to local NVMe storage, providing raw sample data for off-line waveform analysis and CNN classifier training
- RTSA density display (persistence mode) for visualising intermittent slot-based uplink carriers that may be invisible on a standard swept spectrum display

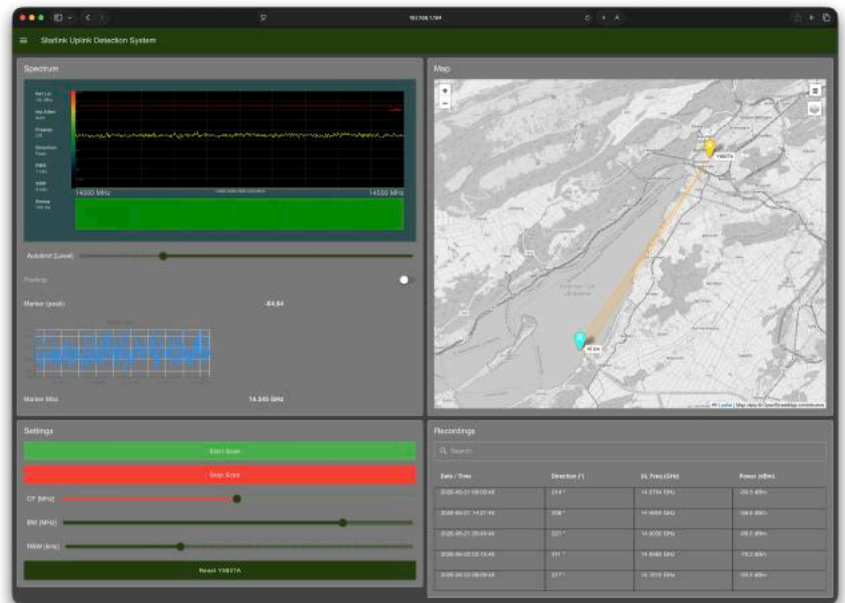
Simple user interface (GUI)

The Starlink Uplink detection system is controlled by a simple user interface GUI, which is accessible from any web browser from a connected PC, Laptop or Tablet.

The display contains of a map with GPS located position of Y9827A and show the beam direction of the detected Starlink Uplink user device. The spectrum displays the signal and a time graph is showing the detected power level over time.

The operation can be simply started and stopped by a button. The detections of Starlink signals are shown in a table, for historical direction reporting.

The user interface can be easily adopted to specific user needs, such as the storage in a local database or the automatic generation of reports or generation of alarms to 3rd party systems.



TDOA geolocation of Starlink terminals

Passive geolocation of an active Starlink terminal is achievable through the same TDOA architecture used by the Y9827A for ground-based RF emitter localisation. Two or more Y9827A units deployed at separated locations capture simultaneous IQ recordings of the Starlink uplink, synchronised via GPS 1PPS timing. The 150 MHz signal bandwidth and 200 MSPS IQ sampling provide sub-nanosecond timing resolution, translating to metre-level range differences between nodes.

The boot-phase scan window provides an especially favourable TDOA opportunity: the terminal transmits predictably across the full band for 20–30 seconds frequency hovering, giving the multi-receiver array a stationary, high-SNR signal to correlate. During active uplink operation, TDOA correlation must track the hopping carrier across multiple dwell periods, requiring a wide-span receiver and spectrogram-based time-frequency fingerprinting rather than simple power detection.

For single-receiver or narrowband scenarios, Power-of-Arrival (POA) geolocation provides a complementary 50–500 m accuracy estimate. The Y9827A platform implements a minimum-variance hybrid fusion architecture that adaptively combines TDOA and POA in real time as a function of signal bandwidth, synchronisation quality, and measured SNR.

AI signal classification: CNN-based recognition

Both Starlink uplink signal classes have been integrated into the Y9800A CNN and LSTM classifiers training pipeline as distinct labelled categories. The boot-phase scan pattern and the wide flat-PSD active carrier are spectrally unique relative to all signal classes previously in the Y9800A database (LoRa, Sigfox, BLE, Zigbee), allowing reliable discrimination with minimal false alarms.

The CNN processes time-frequency spectrogram representations of the captured IQ data, identifying modulation characteristics, spectral shape, and temporal patterns. The LSTM layer provides anomaly scoring based on the learned pattern-of-life of the monitored Ku-band spectrum — a terminal that activates at an unexpected time or location is flagged even before the CNN classification completes. Custom CNN models for Starlink detection can be trained using the YOTASYS Y9900A service from operator-specific IQ capture datasets.

Technical specifications

RF specifications (based on Y9827A)

Parameter	Value	Unit	Comment
Frequency range / bandwidth	9	kHz	RX lower frequency limit
	up to 20	GHz	RX upper frequency limit (see datasheet)
	2 .. 150	MHz	Realtime / IQ Bandwidth
Antennas	1		RX Antenna on front connector N(f)
Sampling rate	200	MSpS	ADC/DAC sample rate at 32bit resolution
Signal Bandwidth	0.036..150	MHz	
Bit resolution	8, 10, 16 or 32	bit	Integer or floating format
Trigger source	Free run External 1/2 Video		
Capture Memory	2	TB	Internal at Y9827A
GNSS Antenna	1		RX Antenna on front connector SMA(f)

The RF specifications are depending on setup and configuration of Anritsu MS27200A.

Disclaimer

The specifications and instructions for our customers in this document reflect the product engineering level at the time of manufacturing. Please consider the valid data sheet release at a time. For questions please contact the YOTASYS customer service. YOTASYS AG accepts no liability for damages resulting from unprofessional installation or application or misuse for a purpose. This disclaimer also includes damages to third parties. It is the customer's responsibility to check the delivered products and immediately notify YOTASYS AG of detected faults. It is also the customer's responsibility to test the delivered product on its applicability for the intended purpose. YOTASYS AG will accept no liability or responsibility for their products if a product or a YOTASYS system is combined or used together with third-party products, i.e. products from other companies than YOTASYS AG. Jurisdiction in all legal disputes concerning product liability has the courts of the canton of Bern/Switzerland. Swiss law applies.

For more information and the newest data sheet releases go to: www.yotasys.com

YOTASYS AG

Aarbergstrasse 46
CH-2503 Biel/Bienne
Switzerland

www.yotasys.com
info@yotasys.com