Wide-Area “Sky-Free” Positioning, Navigation, Timing and Data

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UrsaNav

GPS Timing-Dependent "High-Impact" Systems

- Telecommunications Networks
  - Landline and mobile telephone systems
  - Paging systems
  - Computer networks and the internet
- Energy and Power Systems
  - Energy plants & substations
  - Power grid phase synchronization
  - Flow control
  - Nuclear plants
  - Dams
- Banking & Finance
  - Stock trading
  - ATM transactions
- Agriculture

GPS Timing-Dependent "High-Impact" Systems

- Transportation Systems
  - Maritime: ECDIS, DSC, and AIS
  - Aviation: NextGen, NAS
  - Positive Train Control
  - Intelligent Transportation System
- Emergency Services
  - E-911 or E-112
  - Land Mobile Radio (LMR) network
- Military / Defense
  - C4IT Systems
  - Secure communications systems
- Other Systems/Services
  - Critical manufacturing
  - Shipping; Port operations

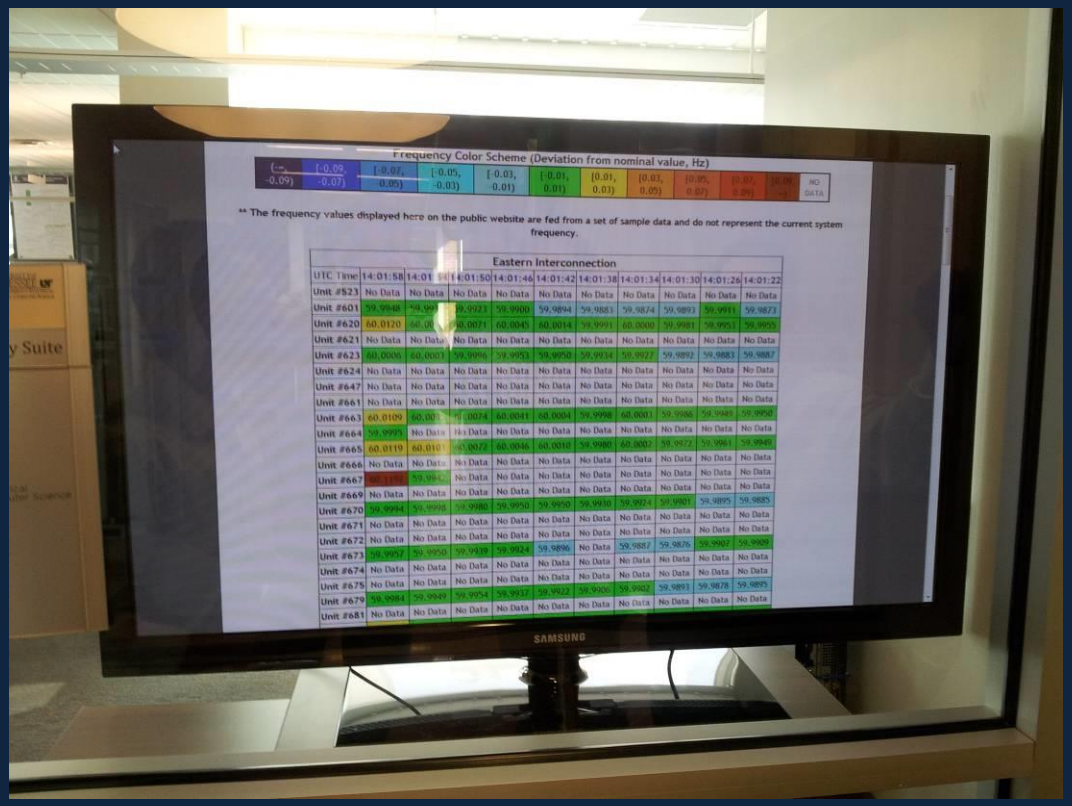
*Of the (18) CIKR sectors, (15) use GPS **timing**.*

*GPS **timing** is deemed **essential** for (11) of the sectors.*

[Source: Department of Homeland Security]

Example: SmartGrid

- SmartGrid sensors need UTC timing and frequency for accurate measurement of the power grid phase
- Sensors don’t provide data without time synchronization
- The use of GPS timing modules with antennas near windows has issues



Why is an Alternative to GPS Timing Necessary?

GNSS/RNSS Vulnerabilities

- Performance degradation
  - Ionosphere & solar activities (natural)
  - Unintentional & intentional (human factors)
- Signal blockage
- Spectrum competition
- Common signal use across GNSS
- Radio frequency interference
- System anomalies & failures
- Jamming
- Spoofing & Counterfeit Signals

Low-cost "personal privacy devices"

100W "Super" Jammer (Range over ½ mile – Plugs into cigarette lighter*)

150W L1 – L5 "Full Band" Jammer (Range up to ¼ mile*)

* Range as advertised on the supplier's website. Independent tests have shown significantly further ranges for lower output power.

LF in the USA: A Way Ahead

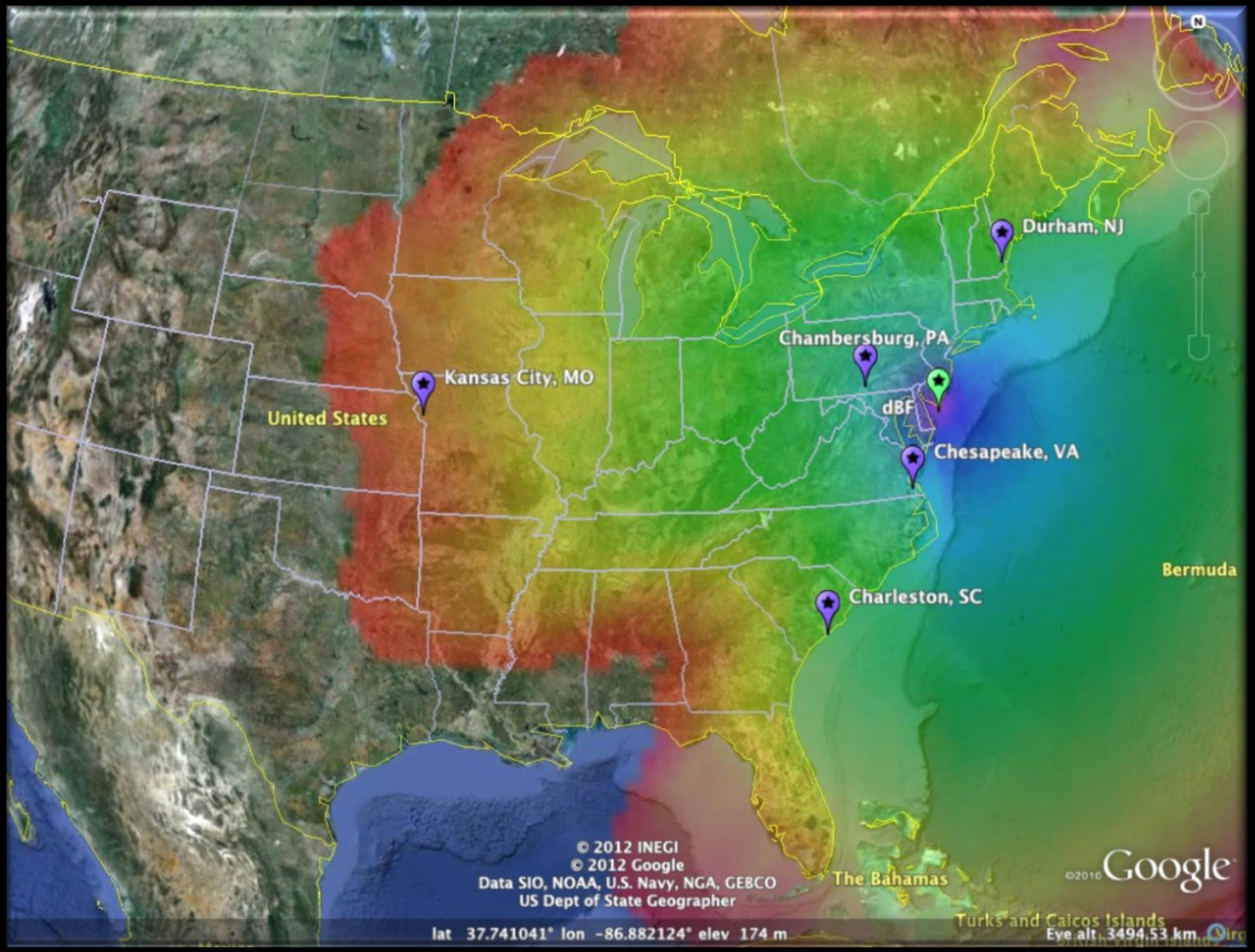
- September 2011 DHS report to Congress
  - GPS timing important
  - Concern for a lack of a backup(s)
- DHS investigating alternatives
  - Precise time via wire/fiber
  - Asked USCG to investigate wireless time transfer
- **CRADA (Effective 02/13/2012)**
  - Two years after Loran-C Termination
  - Promotes R&D efforts; tech transfer
  - Not a contract; no exchange of funding; not government "sponsored"
- Objectives
  - Research, evaluate, document
  - Time. Frequency. Data. (Position.)

Disclaimer: The USCG has no intent to acquire, operate, or provide wireless time technology or associated services.

Initial Testing & Results

- Ongoing testing since February 2012
- Several test locations with **UrsaNav** receivers
  - Leesburg, VA (142 miles)
  - Chambersburg, PA (160 miles)
  - Chesapeake, VA (170 miles)
  - Burlington, MA (310 miles)
  - University of New Hampshire (354 miles)
  - Charleston, SC (505 miles)
- Using a **Nautel** NL-series transmitter
- Transmitted to within 10 ns of UTC
  - Based on TWSTT between USNO & DBF
- **Symmetricom** ATS-6501 Time & Frequency Reference at test locations
- Validated proper reception and tracking of signals to at least 1050 miles (Kansas city, MO)

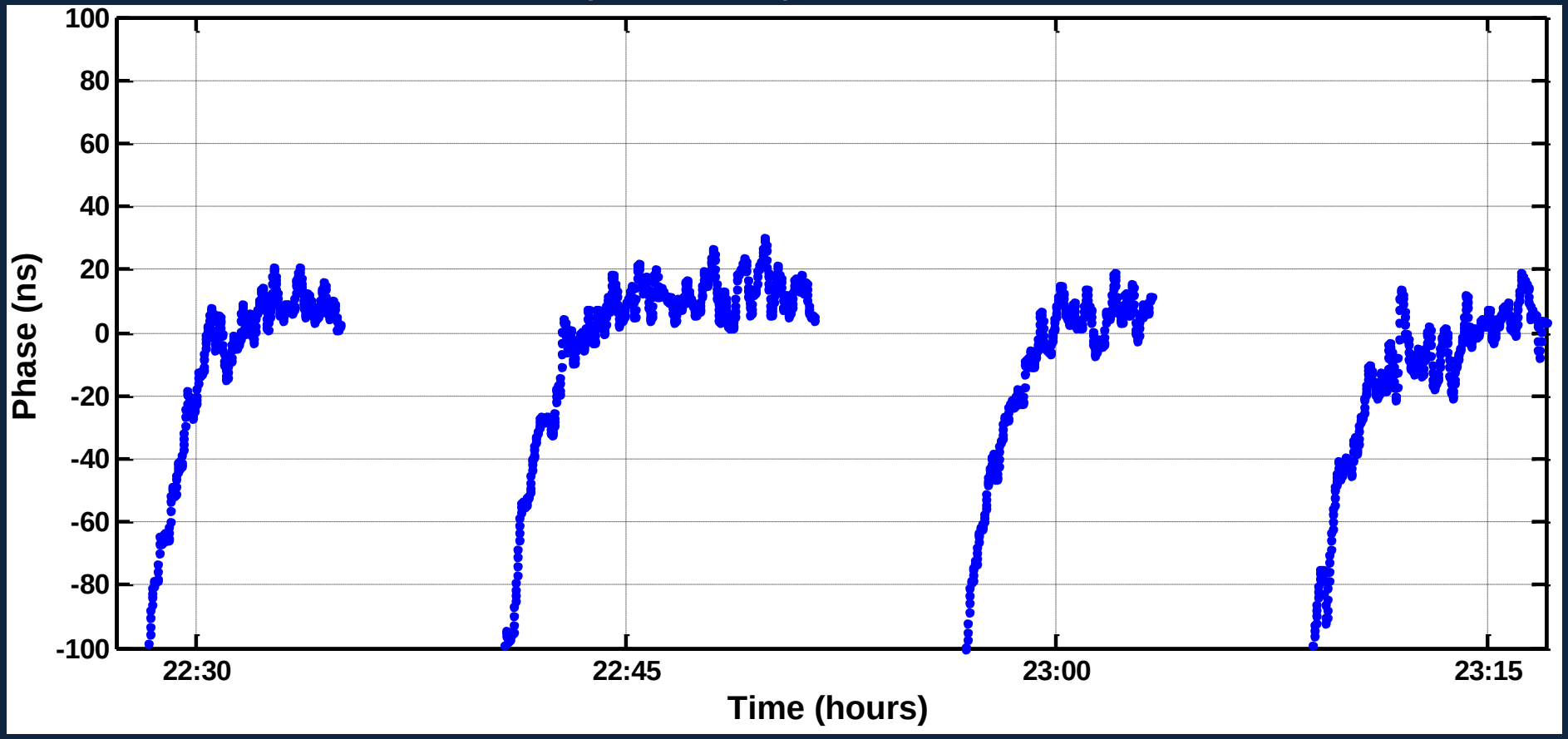
Verified eLoran T, F, & D Coverage



Proper reception, tracking, & decoding of signals from dBF at Kansas City, MO – 1,050 miles

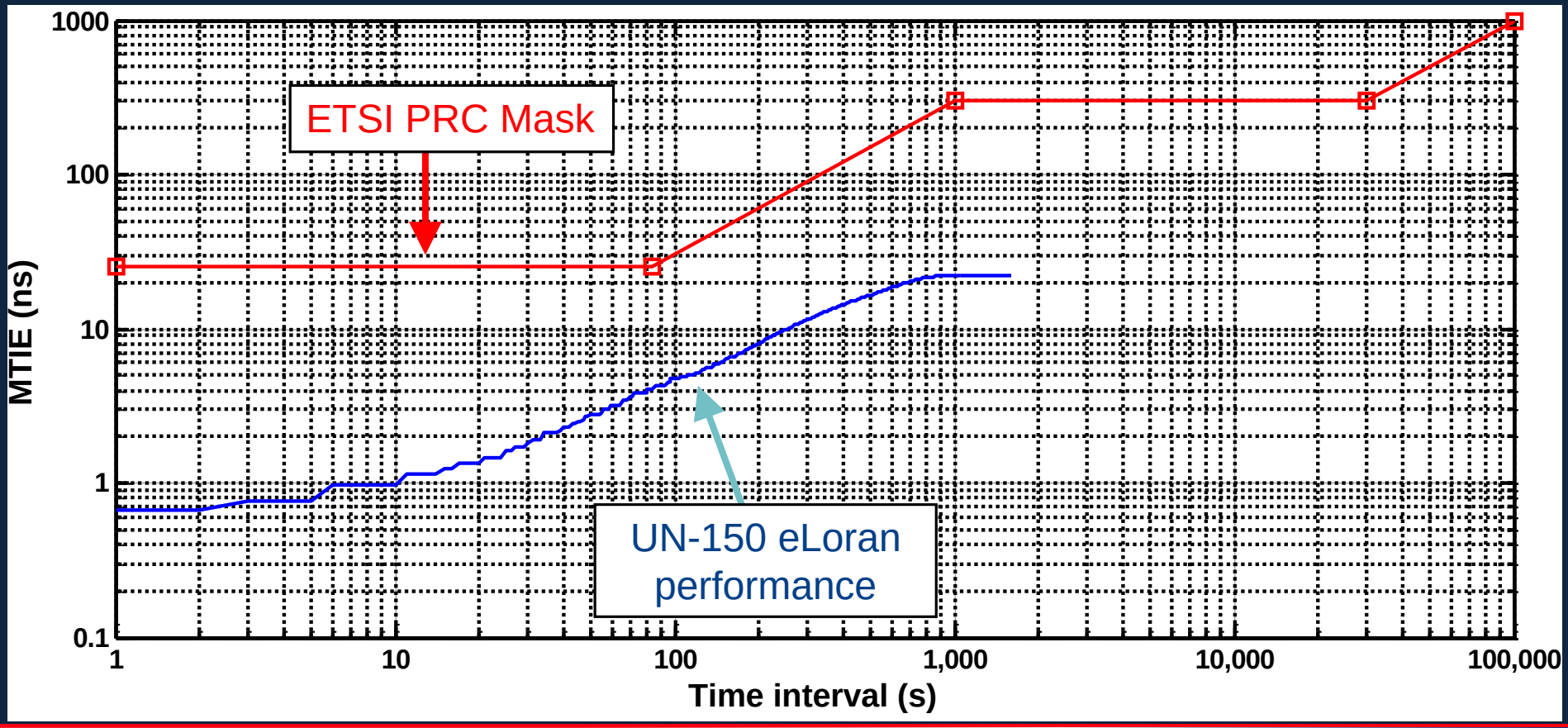
Initial Testing & Results

- UN-150 receiver consistently steered to UTC through intentional restarts (at at 22:25, 22:35, 22:53 and 23:04 hours)
- Short duration testing showed UTC recovery to within 50 ns at Charleston test location (505 miles)



Initial Testing & Results

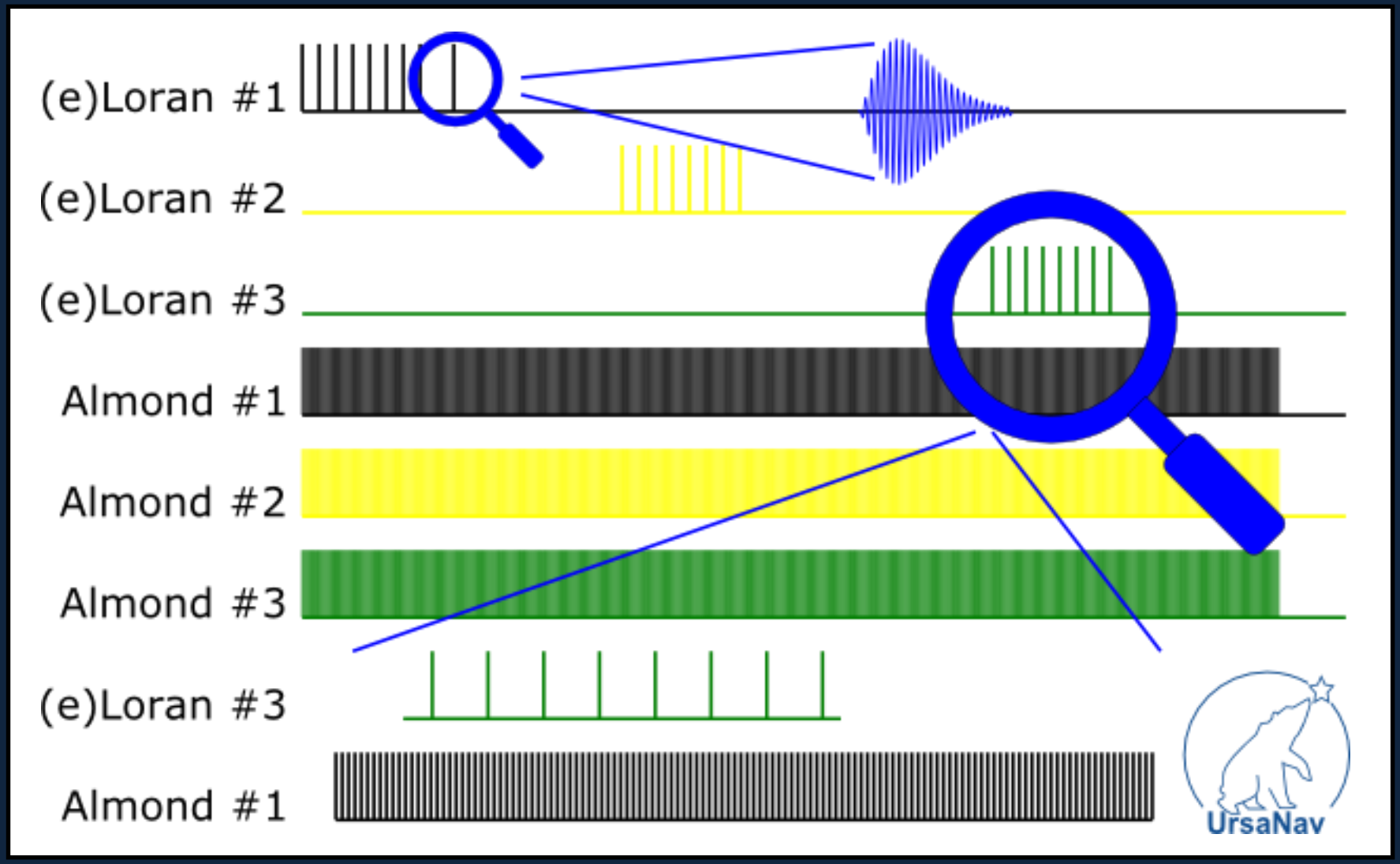
- MTIE performance requirements for ETSI Primary Reference Clock standard successfully met



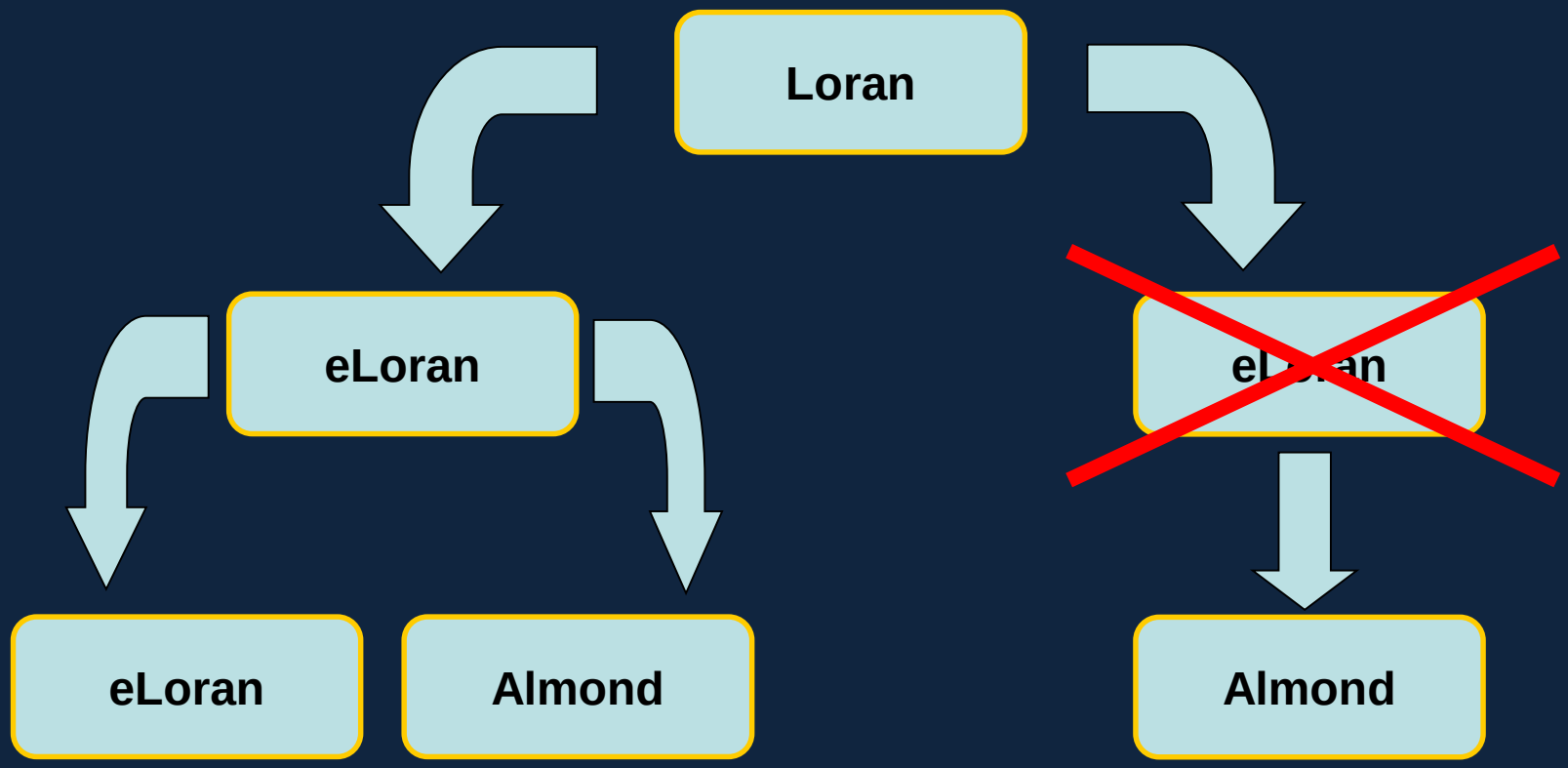
Introducing: Almond Codes

- Power per pulse does not increase
  - Same transmit antenna, same base insulator, same (advanced) transmitter, same SDR architecture → **no hardware changes necessary** (except: TX power supply)
- Significant increase in number of pulses transmitted
- Optimized pulse shape
  - Taking advantage of modern transmitter capabilities
  - Meets 90-110 kHz spectrum requirements
- Orthogonal codes
- Provides increase of 16 dB of received signal power
- Eliminates Cross Rate → ≈10 dB less noise
- SNR improvement: 26 dB
- Receiver can integrate and improve SNR further (under stationary conditions with quality receiver clock)

Almond Codes



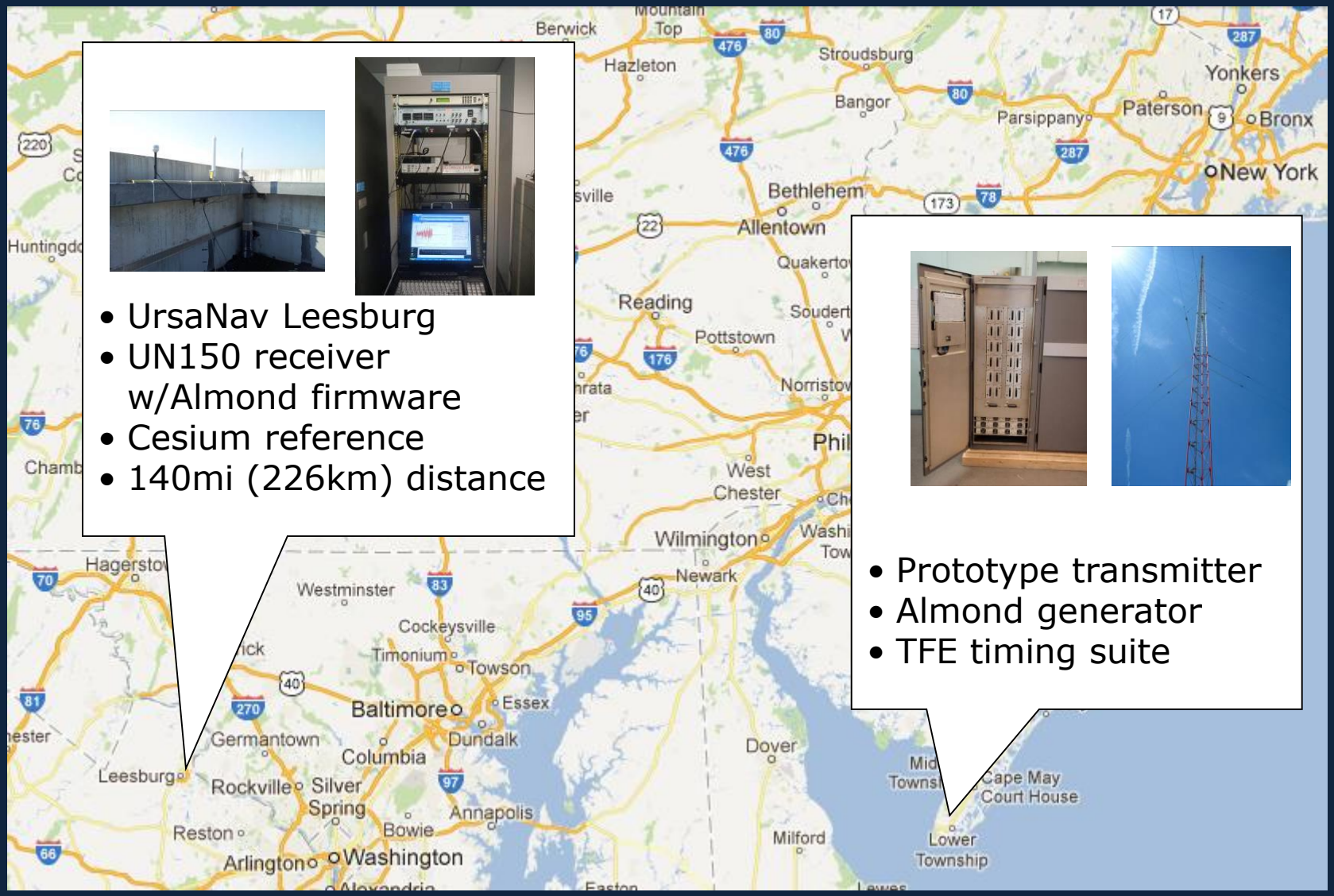
Implications



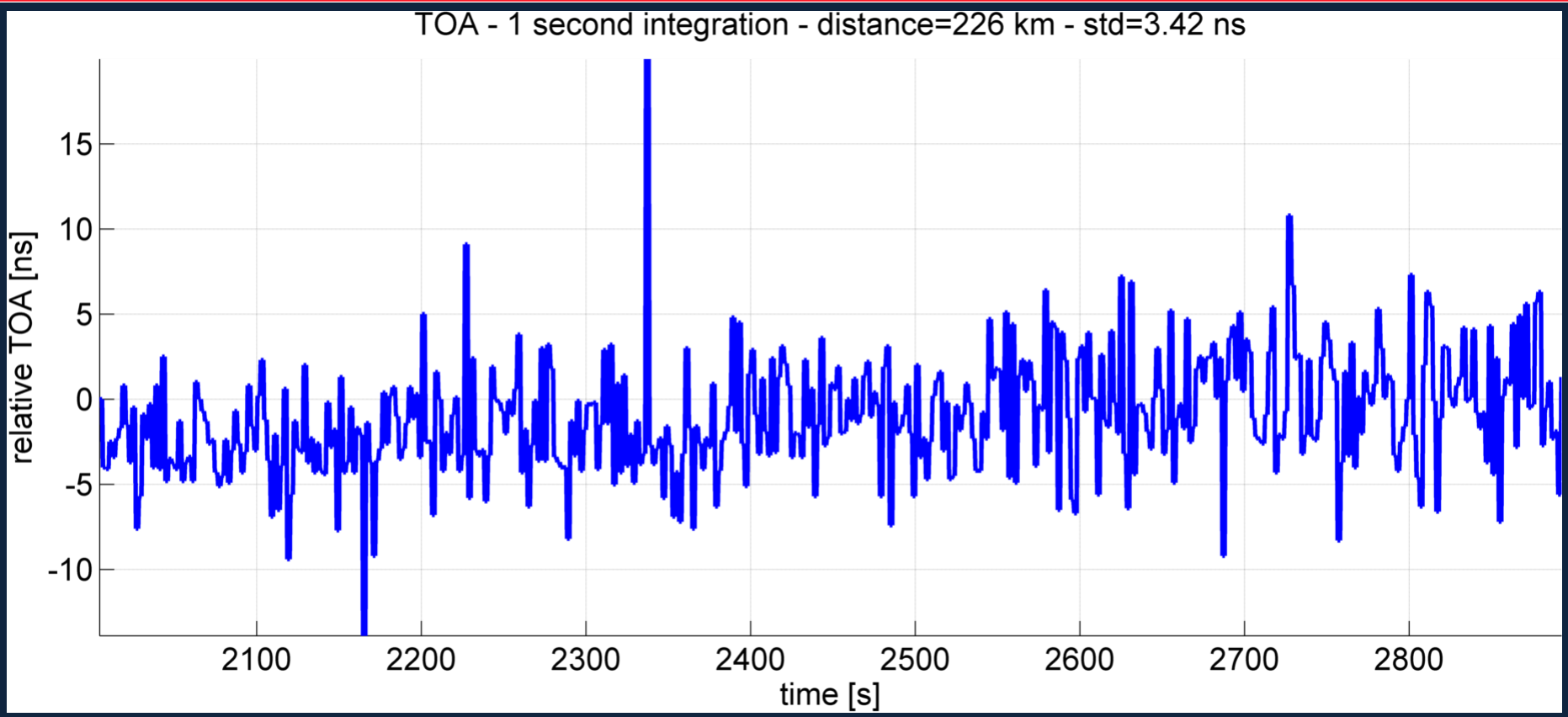
eLoran and Almond can co-exist
Almond will operate in 'compatibility mode'

Full Almond potential

Almond transmission trials



Tracking performance Almond codes

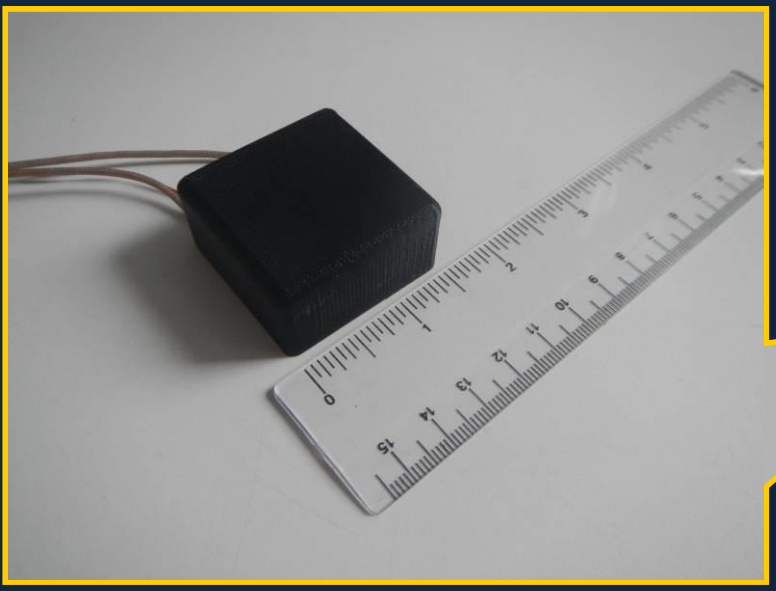


- Using 1.2 kW ERP transmitter @ 226 km distance
- Receiver set for 1 second integration
- 1-sigma value: 3.42 ns (raw measurements)

First blush indoor performance test

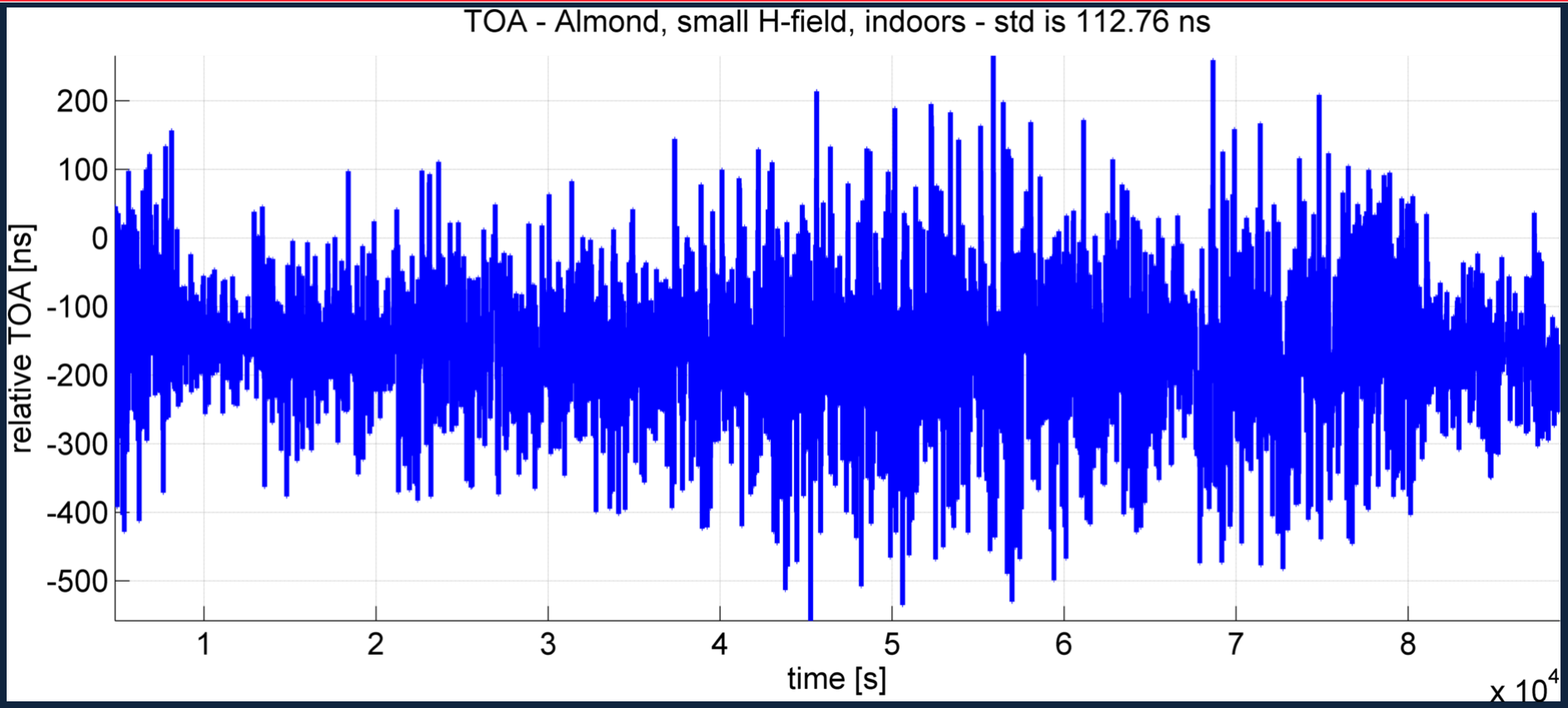
Prototype H-field antenna

Dimensions: 38 x 38 x 19 mm
1.5″ x 1.5″ x .75″



- Smallest H-field antenna to date
- Antenna in noisy office environment
- 5 meters away from outside wall

Tracking performance – indoor antenna

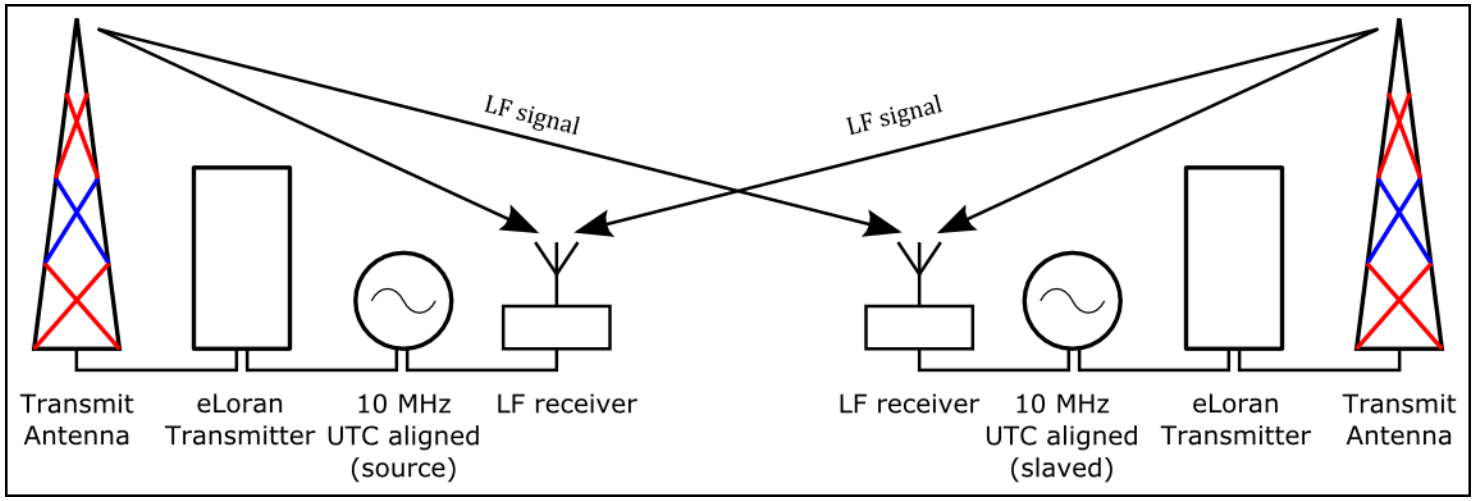


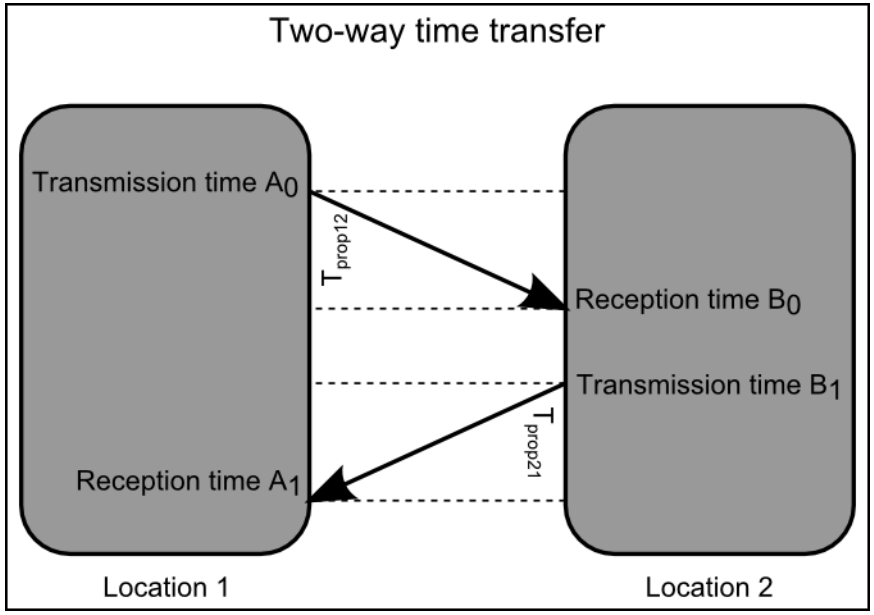
- Using 1.2 kW ERP transmitter @ 226 km distance
- Receiver set for 32 seconds integration (equivalent to 1s integration w/40 kW transmitter)
- First blush attempt; uncontrolled environment
- 1-sigma value: 112.76 ns

Integration

- Loran signal integration was limited by ‘residual crossrate’ interference
- Through integration, receivers can make life better for themselves
  - System will work in more adverse conditions
- ‘Dial-down’ tests on our test facility show that <1 Watt (not: kW) signals still useable
- Network can be extended with multiple low-power transmitters
  - Extra monitors in the field could have capability to transmit back at low power

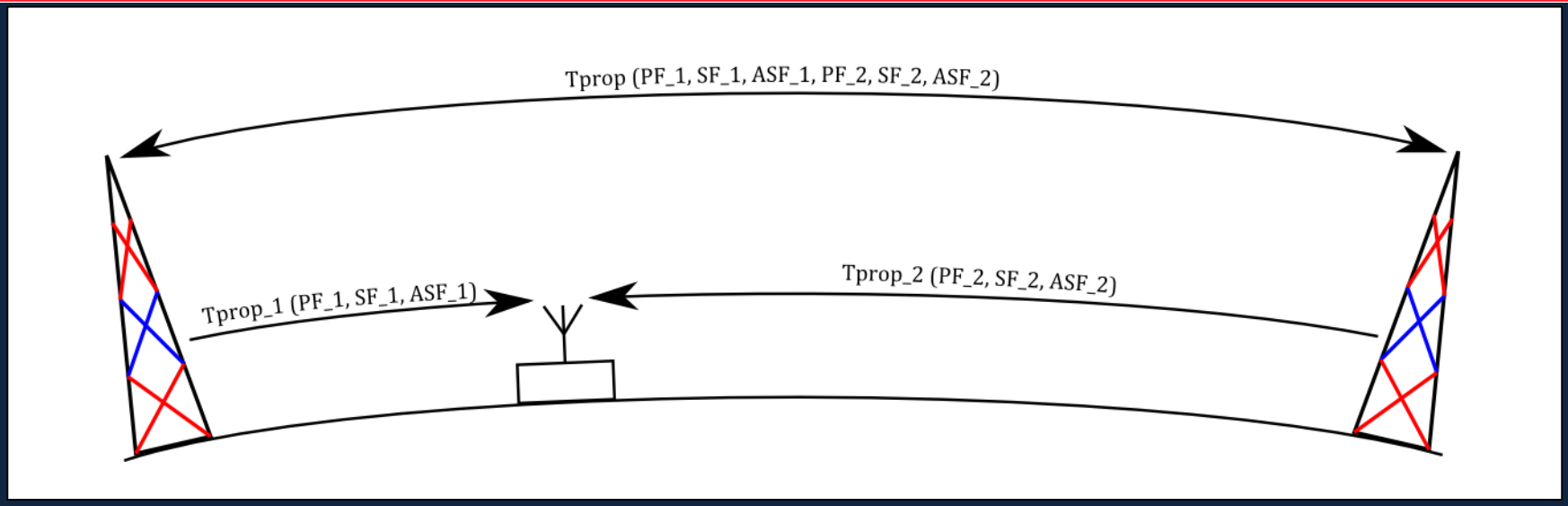
New possibilities for solving propagation time





$$T_{prop} = \frac{(B_1 - B_0) - (A_1 - A_0)}{2}$$

Solving for propagation time on the baseline



- Receiver can determine:
  - Tprop = Tprop_1 + Tprop_2 (via LF data channel message)
  - ΔT = Tprop_1 – Tprop_2 (via direct measurement)
- Tprop_1 and Tprop_2 can be solved
  - Independent of ASF values (!)
- Receiver can recover time w/o offsets due to propagation
  - When receiver is on the baseline between transmitters
  - Under the assumption that propagation is a linear phenomenon
  - Applies to both eLoran and Almond systems

Almond – new possibilities

Almond features:

- Significantly improved tracking performance compared to legacy LF
- Reliable reception possible under more adverse conditions than before
- Reliable reception using very low power transmitters over significant distance

Physics doesn't change:

- LF signal propagation characteristics (ASF fluctuations)

Almond allows us to:

- Make LF Timing (and positioning) work in more places
- Optimize our network for dealing with LF propagation effects
- Possibly add new low power transmitters at monitor sites to measure actual propagation effects in greater detail, in real time

Future Plans

- Follow-on testing currently ongoing
- Come on-air with second transmitter
- Demonstrate Two-Way Low Frequency Time Transfer (TWLFTT)
- Test UTC Timing recovery on/away from baseline
- Demonstrate hybrid eLoran / Almond technique
- Add ‘high-speed’ data broadcast capabilities to Almond transmissions (OFDM?)
- Demonstrate feasibility of low-power return transmissions
  - Goal: Design network such that we can provide an upper bound for timing errors experienced by users

- Continue sky-free reception tests (indoors/tunnels/caves/…)
- Optimize new UN151 receiver for LF/MF reception
- Optimize UN151 receiver for various types of antenna combinations

An Alliance of Expertise

- **An alliance of global expertise**:
  - high-power RF
  - precise time & frequency
  - advanced multi-mode/ multi-purpose receivers, and
  - operational expertise
- **We have the solutions**:
  - Provide independent UTC timing source w/ indoor reception capability
  - High-speed data channel options available (> 1,200 bps)
  - Meet world-wide APNT requirements
- **The solutions exist today:**
  - A range of fully developed and proof-of-concept technology
  - Next generation LF APNT&D solutions, built upon proven technology and performance
- **We continue to optimize performance**
  - Transmitters, receivers, signals, network design
  - We welcome and support third party research initiatives

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