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

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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]
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.
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

Why is an Alternative to GPS Timing Necessary?

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.
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 dB at Kansas City, MO – 1,050 miles
- UN-150 receiver consistently steered to UTC through intentional restarts (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)
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

(e)Loran #1

(e)Loran #2

(e)Loran #3

Almond #1

Almond #2

Almond #3

(e)Loran #3

Almond #1
eLoran and Almond can co-exist
Almond will operate in ‘compatibility mode’

Full Almond potential
Almond transmission trials

- UrsaNav Leesburg
- UN150 receiver w/Almond firmware
- Cesium reference
- 140mi (226km) distance

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

\[ T_{prop} = \frac{(B_1 - B_0) - (A_1 - A_0)}{2} \]
Receiver can determine:

- $T_{prop} = T_{prop\_1} + T_{prop\_2}$ (via LF data channel message)
- $\Delta T = T_{prop\_1} - T_{prop\_2}$ (via direct measurement)

- $T_{prop\_1}$ and $T_{prop\_2}$ 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 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 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
Your Alternatives to the Sky™
Safeguarding your mobile communications, banking, and utilities.

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