Aligned with your needs.

Development of an Integrated GPS-eLoran Signal Simulator

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University of Rhode Island

ALION
SCIENCE AND TECHNOLOGY

Outline of this talk

- **The need for Loran**
  - Rewind previous speakers and think about what they said
- **Our simulator – the GeLSim 100**
  - The device for testing your eLoran receiver
- **Conclusions**
  - Come visit us with your checkbook

Why eLoran?

- **Everyone here probably agrees that eLoran is a vital part of the National PNT architecture.**
- **Enough said.**

CNN.com

SCIENCE & SPACE

U.S. official: Chinese test missile obliterates satellite

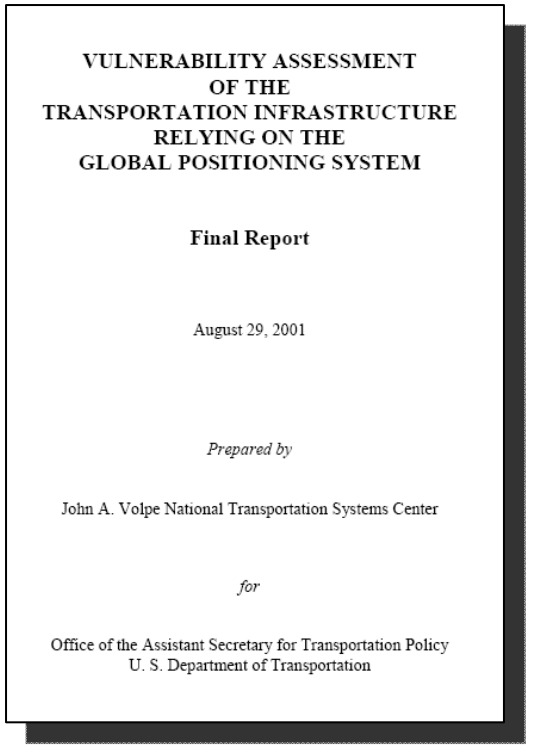
POSTED: 1:47 p.m. EST, January 19, 2007

China's missiles might be able to take out U.S. satellites.

STORY HIGHLIGHTS

- Chinese use a missile to ram and destroy an old, orbiting satellite
- Experts: China now may have ability to knock out U.S. GPS and spy satellites
- Washington issues formal diplomatic protest

WASHINGTON (CNN) -- China last week successfully used a missile to



VULNERABILITY ASSESSMENT
OF THE
TRANSPORTATION INFRASTRUCTURE
RELYING ON THE
GLOBAL POSITIONING SYSTEM

Final Report

August 29, 2001

Prepared by

John A. Volpe National Transportation Systems Center

for

Office of the Assistant Secretary for Transportation Policy
U. S. Department of Transportation

Current Loran-C Coverage

Possible eLoran Coverage

Why an integrated simulator?

- **Integrated GNSS-eLoran receivers are the future**
- **Need to be able to test these receivers**
  - **Manufacturers**
  - **System/service providers**
  - **Government agencies**
  - **Universities**
  - **Others?**

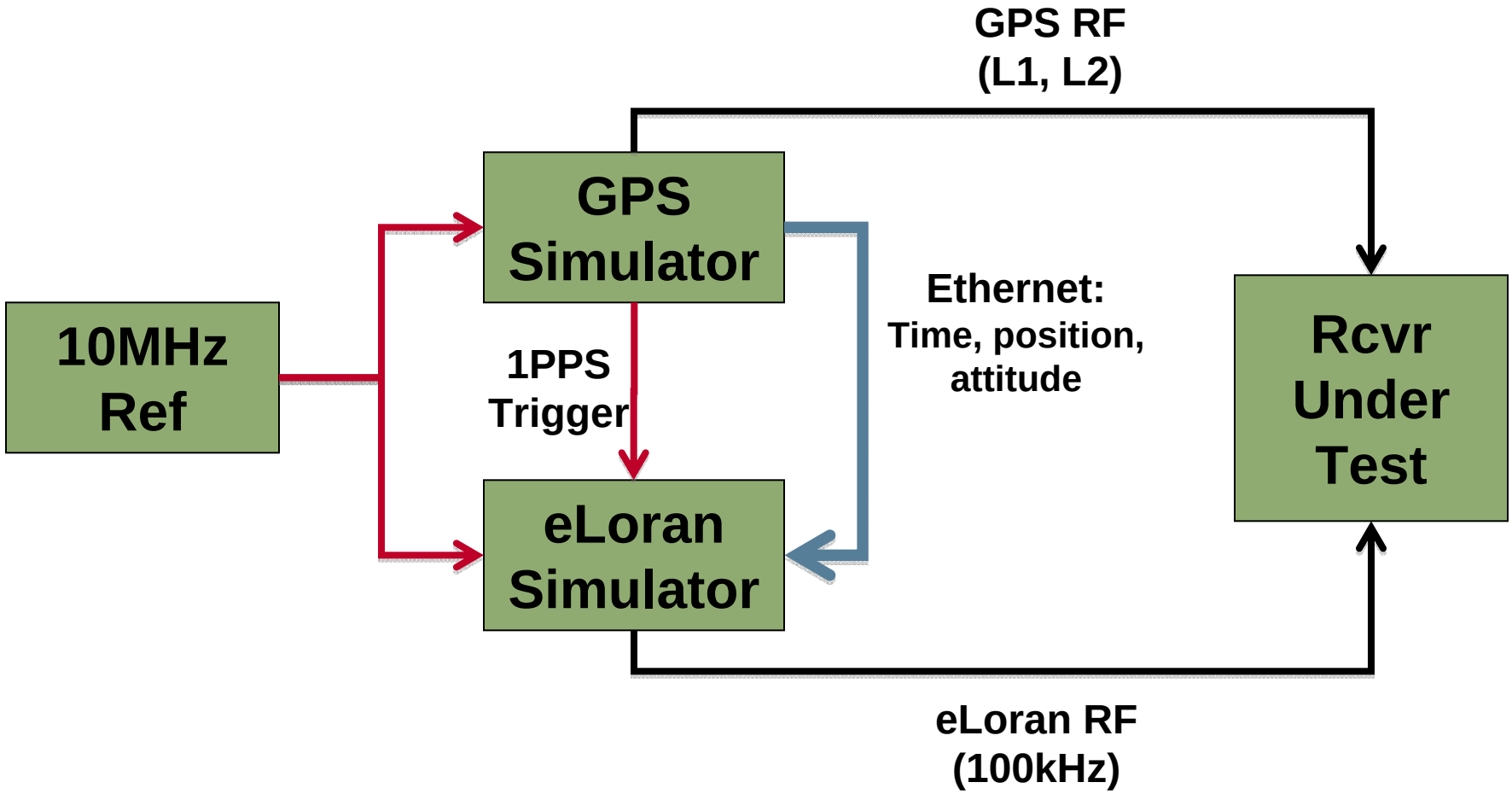
Testing Needed

- **Need to test all aspects of Loran Receiver Performance**
  - **Receiver's ability to demodulate LDC**
  - **Operate in the presence of noise, skywave, and crossrate**
  - **Ability to recognize blinking**
- **Need to test Integration**
  - **Position accuracy and reliability of integrated solution**
  - **Robustness and reaction of receiver to GNSS and Loran outages**
- **Ability to test possible system changes**
  - **New chains / rates**
  - **Multiple phase codes**
  - **Etc.**

GeLSim 100

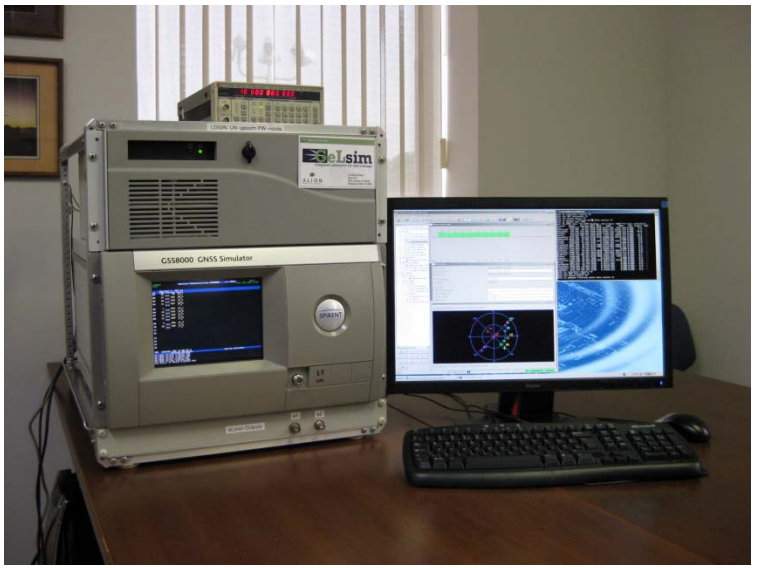
- **Integrated GPS-eLoran signal simulator**
  - GPS and eLoran signals synchronized in time/space
  - Generates both GPS and eLoran signals as user receiver would see them
  - Common scenario – generated on GPS simulator
  - Tied together with common clock
  - Time scale linkage
  - Synch with 1 PPS strobe to start scenario

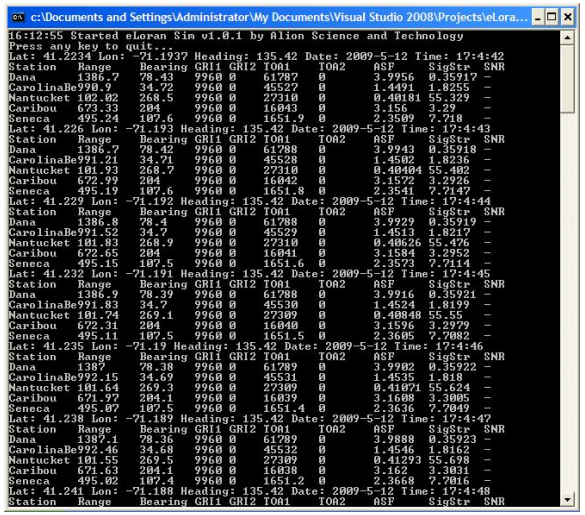
GeLSim 100


GPS RF
(L1, L2)
GPS Simulator
10MHz Ref
1PPS Trigger
Ethernet:
Time, position, attitude
Rcvr Under Test
eLoran Simulator
eLoran RF
(100kHz)

The Components

- **GPS Portion:**
  - **Mated to a Spirent GSS 8000**
    - L1, L2, L5, Glonass, Galileo, DGPS, WAAS available
    - Sophisticated scenario planning
    - Various interference options
- **eLoran Portion:**
  - **Fully configurable**
    - Station locations, rates, emission delays, etc.
  - **Position-based ASFs and signal strengths**
    - Station signal strength based upon predictions (conductivity & terrain)
  - **Vincenty method for TOA delay calculation**
  - **Standard PF and SF calculations**
  - **Loran Data Channel**
  - **E and H-field antenna outputs**





THE LORAN SIMULATOR VERSION 1.1

System Configuration File Features

- **Loran tower names & locations**
  - **Current locations supplied**
  - **New locations possible**

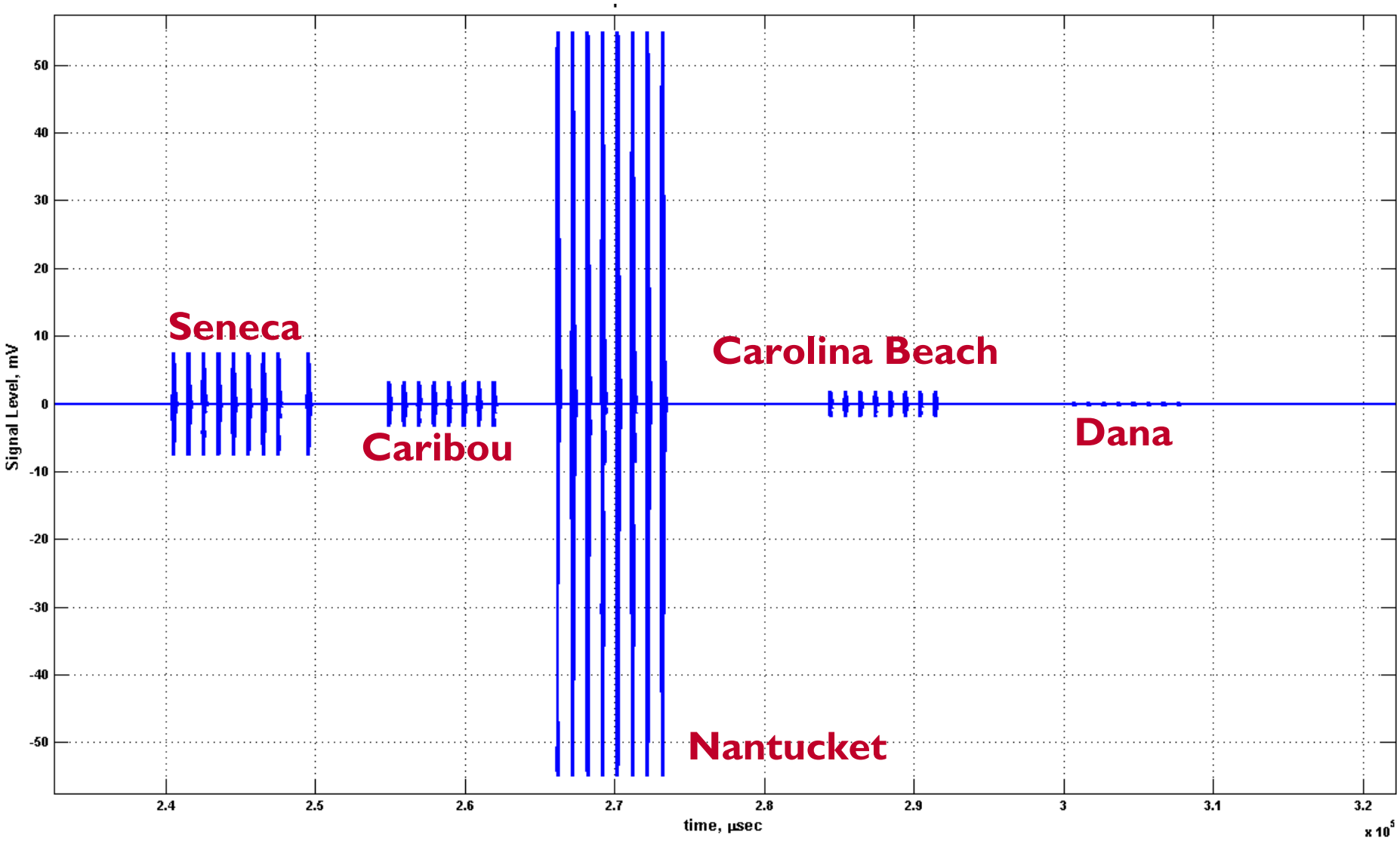
Global selectable features include

- Whether to apply ASF values to all signals
  - Predicted CONUS grid supplied
  - User can modify with their own values if desired
- Whether to apply atmospheric noise to all signals
  - Use either a specified global noise value or a grid based on CCIR models
- Whether to apply skywave or not
  - User specified delay and scale factor
- PCI strobe
  - User selectable station
- Antenna type
  - E- or H-field antenna outputs
- Ninth pulse data
  - Currently either sequential symbols or user specified file of symbols
- Output power scaling
  - Either fixed (specified) scale factor or autoscaling
- Data output (either RF or to file)
  - Each file 1 epoch of passband data
  - User-specified directory
- Antenna rotation offsets
- Antenna upside down or not

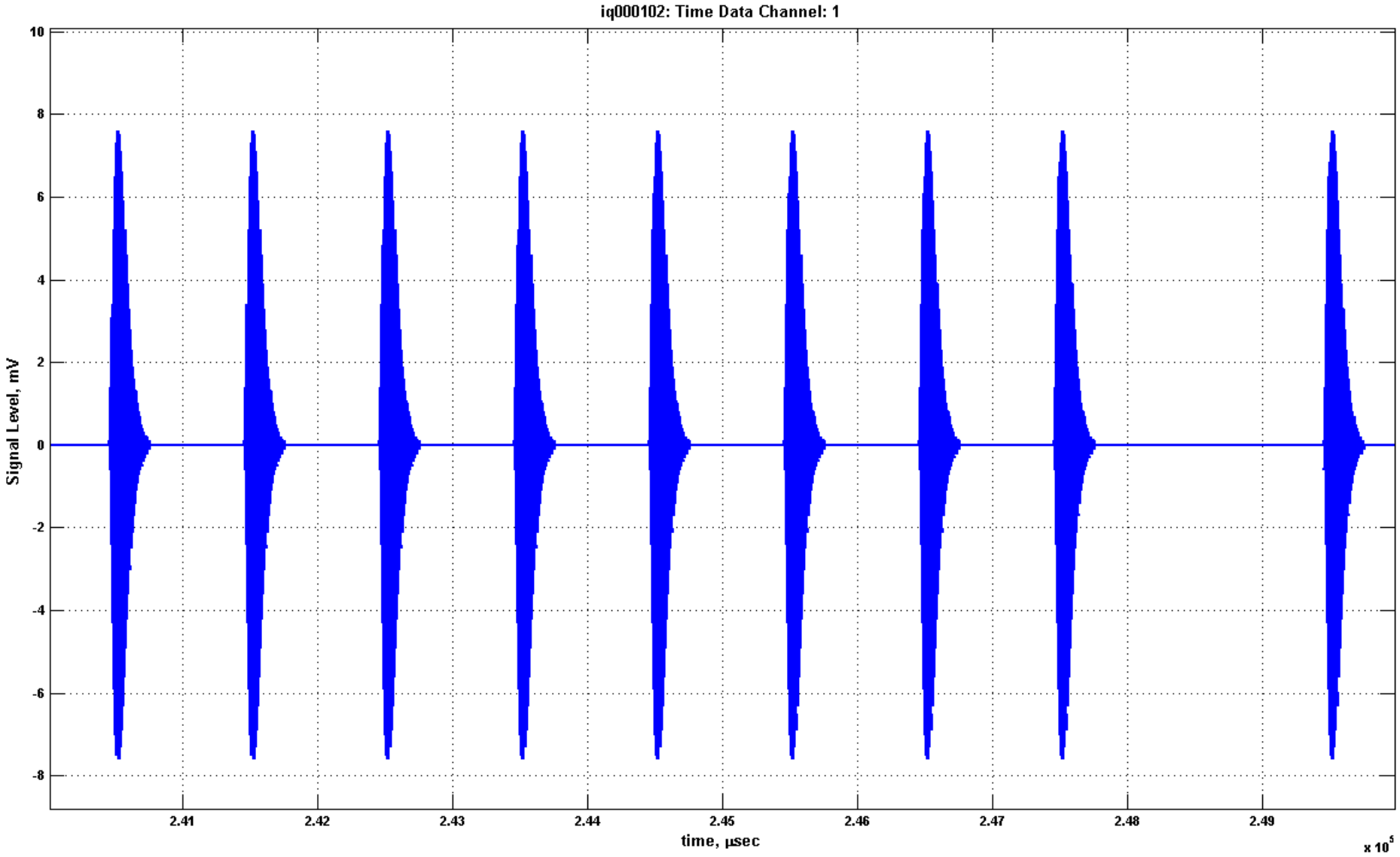
Features on an individual station basis

- Turn individual stations on/off
  - 1 - 30+ parallel Loran Stations
- User configurable chains/rates
  - Existing system chains/rates predefined but these can be changed by the user
- User configurable emission delays
  - Existing system values predefined but these can be changed by the user
- User configurable ECDs
  - Set the ECD desired at the receiver
- User configurable phase codes
  - Standard master/secondary codes pre-set but these are changeable on an individual station level
- Skywave delay parameters
  - Delay and scale factor
- 9th pulse LDC on any station
  - Currently same message on all stations
- System time bias and jitter
  - Offsets applied to all pulses in a Group of the station
- Pulse position jitter
  - Noise in the timing of individual pulses from the station
- Pulse amplitude variation
  - Variation in the amplitude of individual pulses from the station
- Blink on/off
  - User selectable for each station

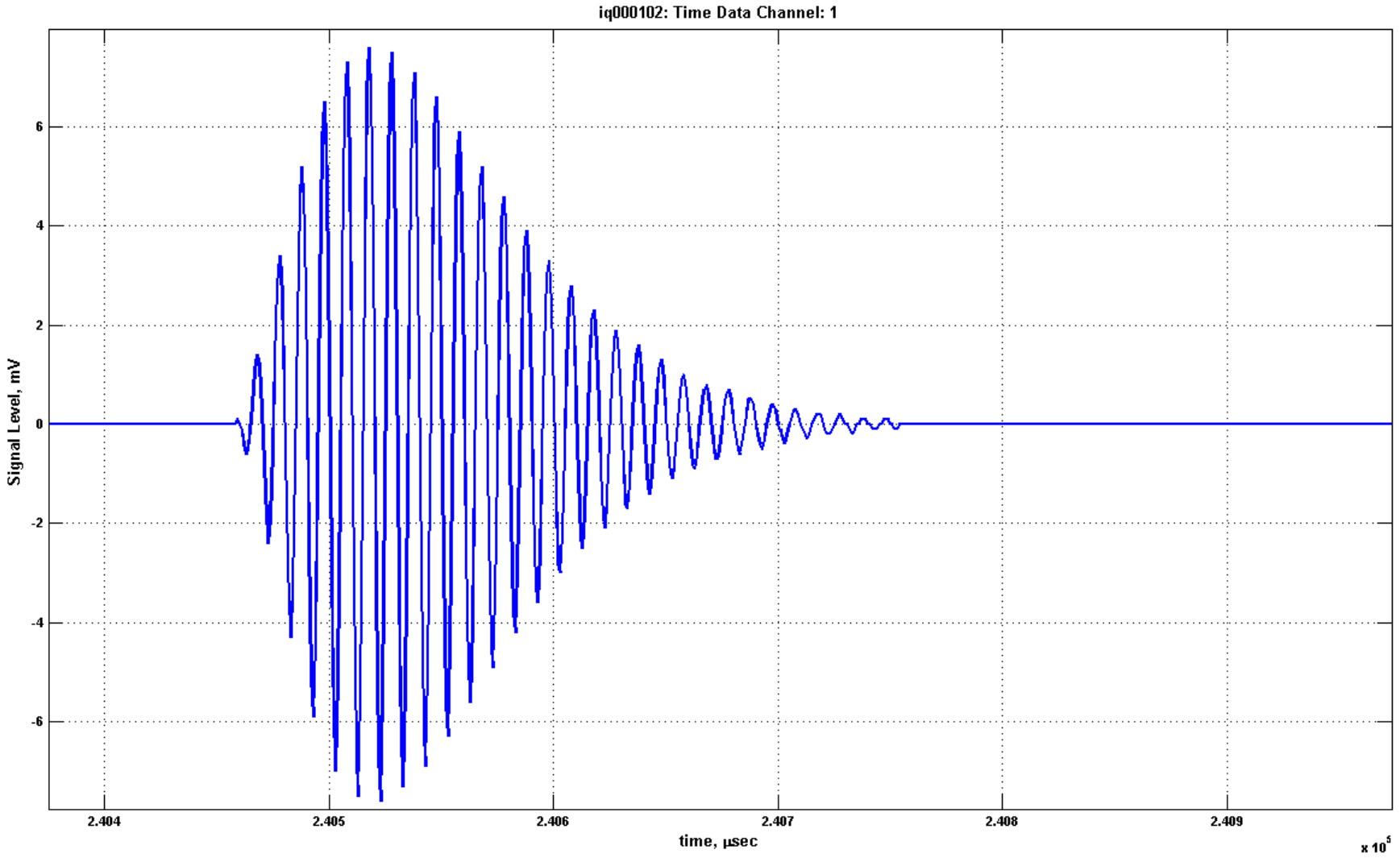
eLoran Simulator Output



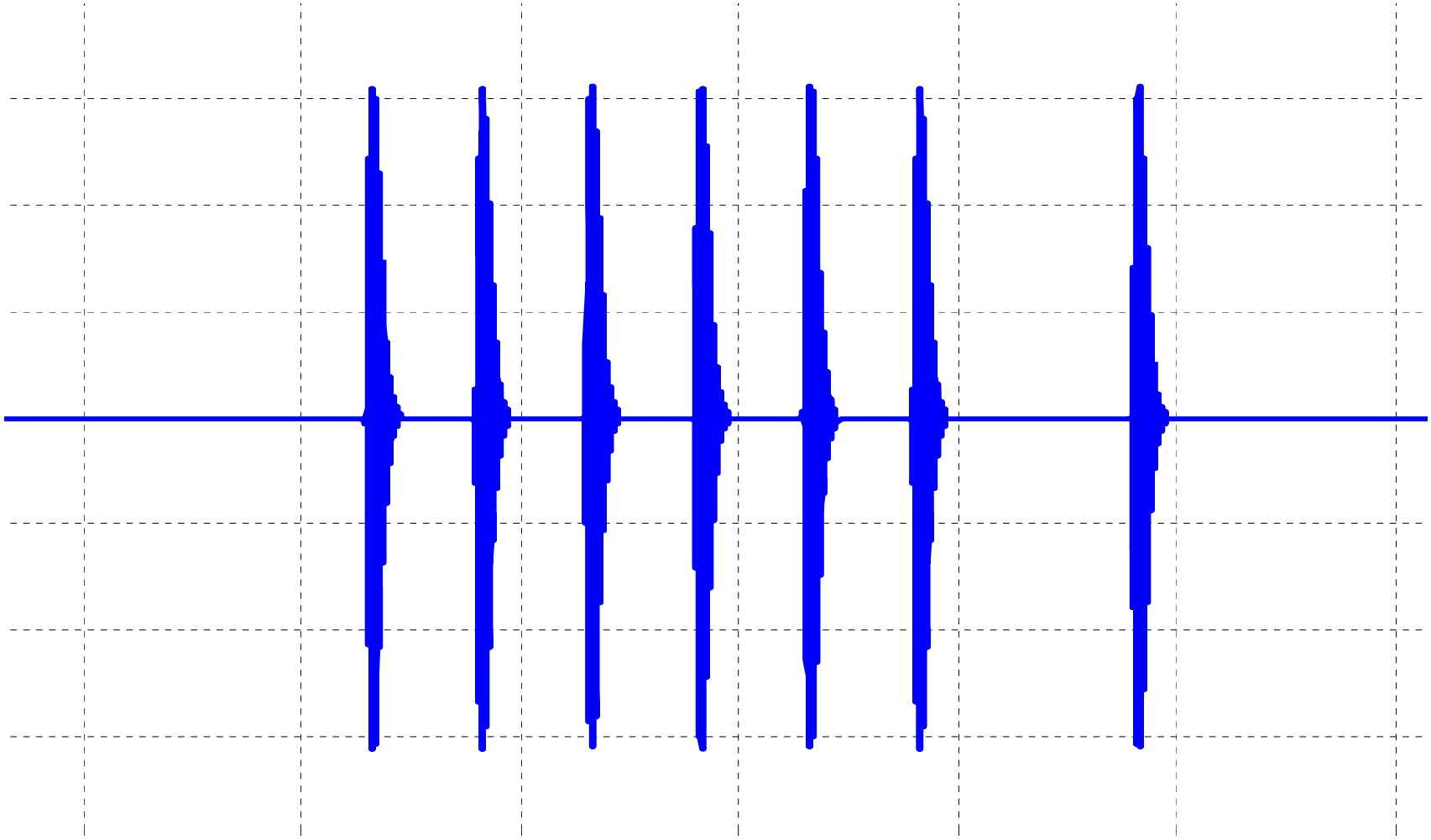
Seneca


iq000102: Time Data Channel: 1
Signal Level, mV
10
8
6
4
2
0
-2
-4
-6
-8
2.41
2.42
2.43
2.44
2.45
2.46
2.47
2.48
2.49
time, µsec
x 10^5

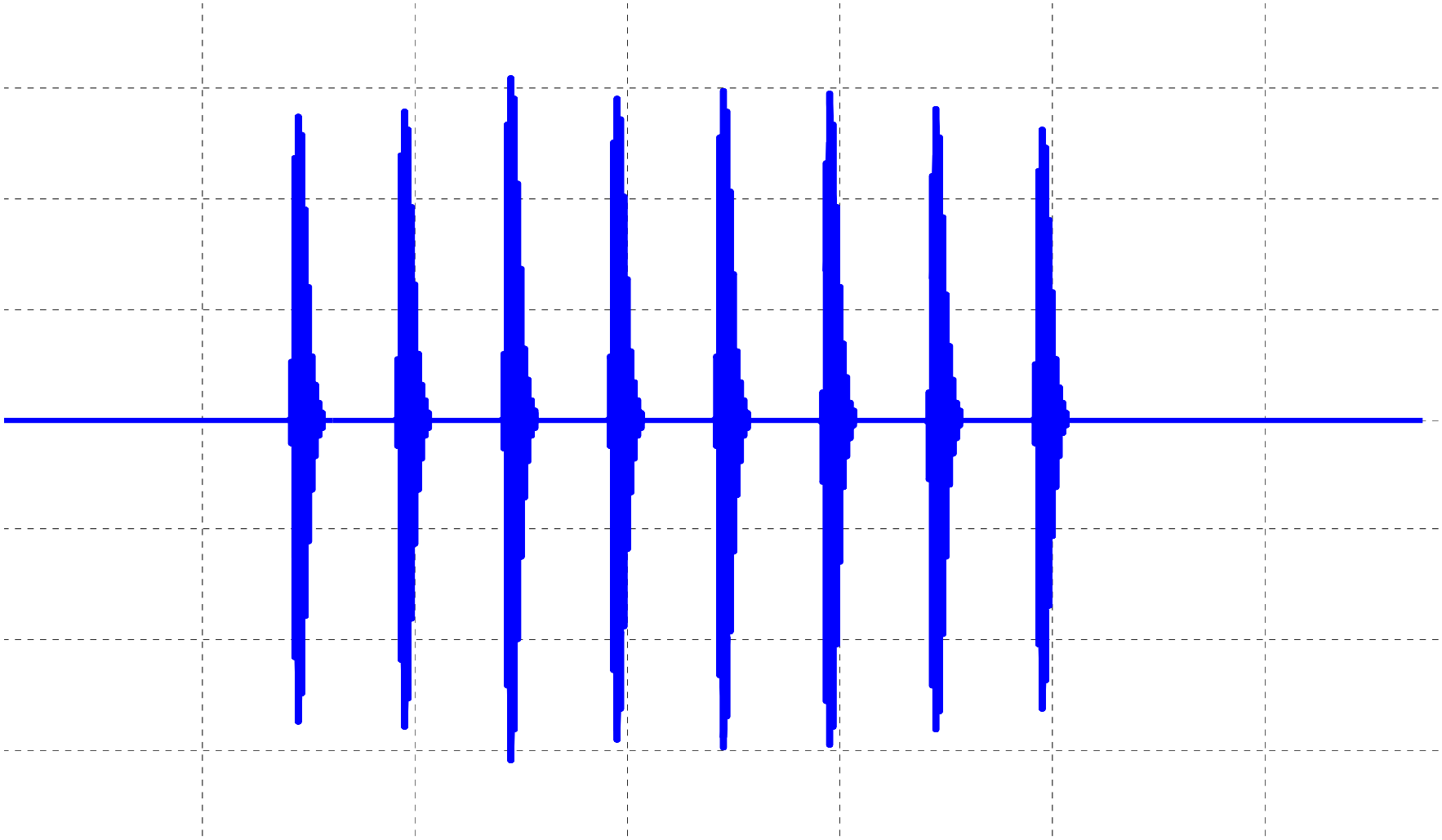
One Pulse


iq000102: Time Data Channel: 1
Signal Level, mV
6
4
2
0
-2
-4
-6
2.404
2.405
2.406
2.407
2.408
2.409
time, µsec
x 10^5

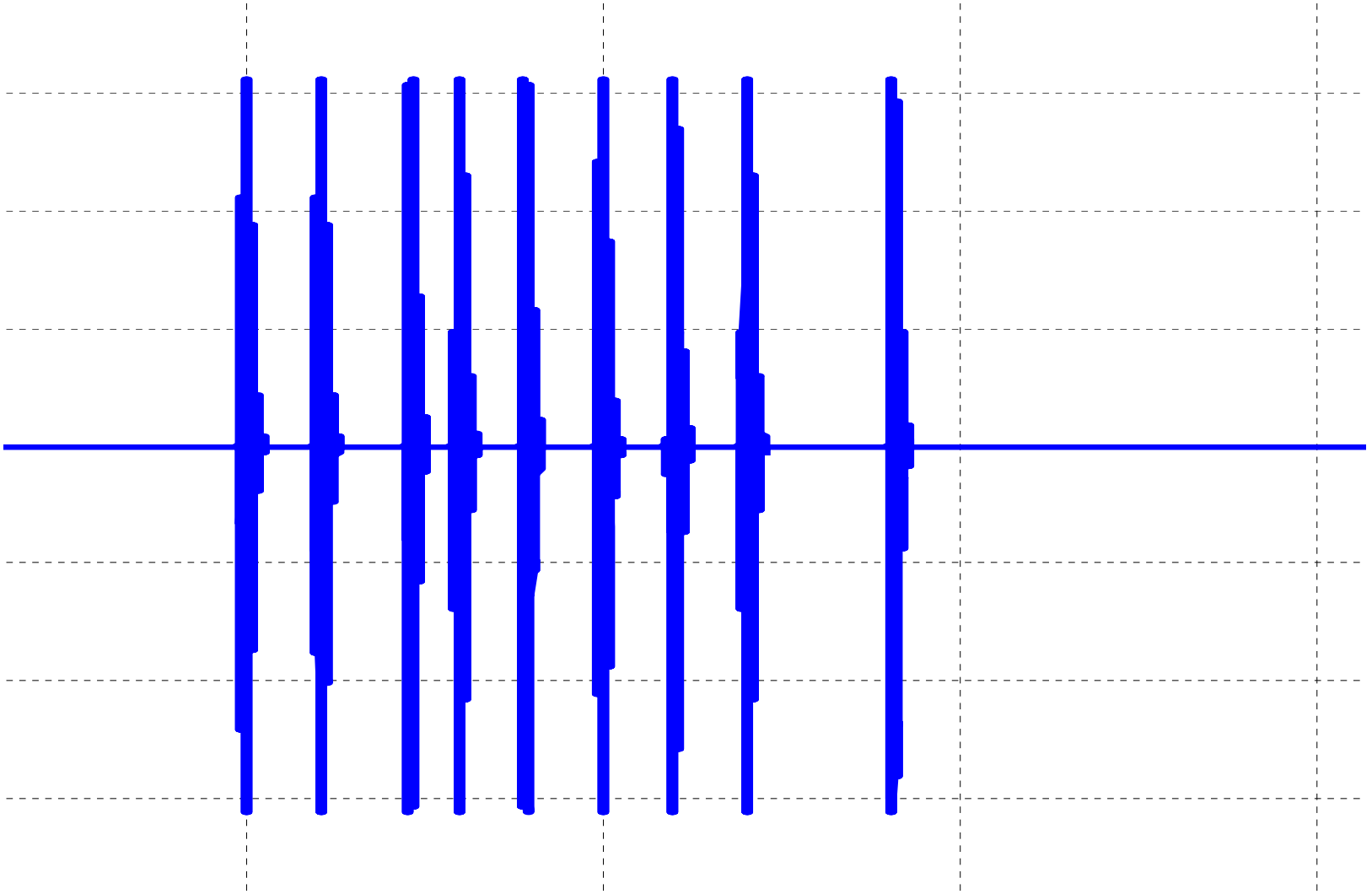
Blink Enabled (Master)



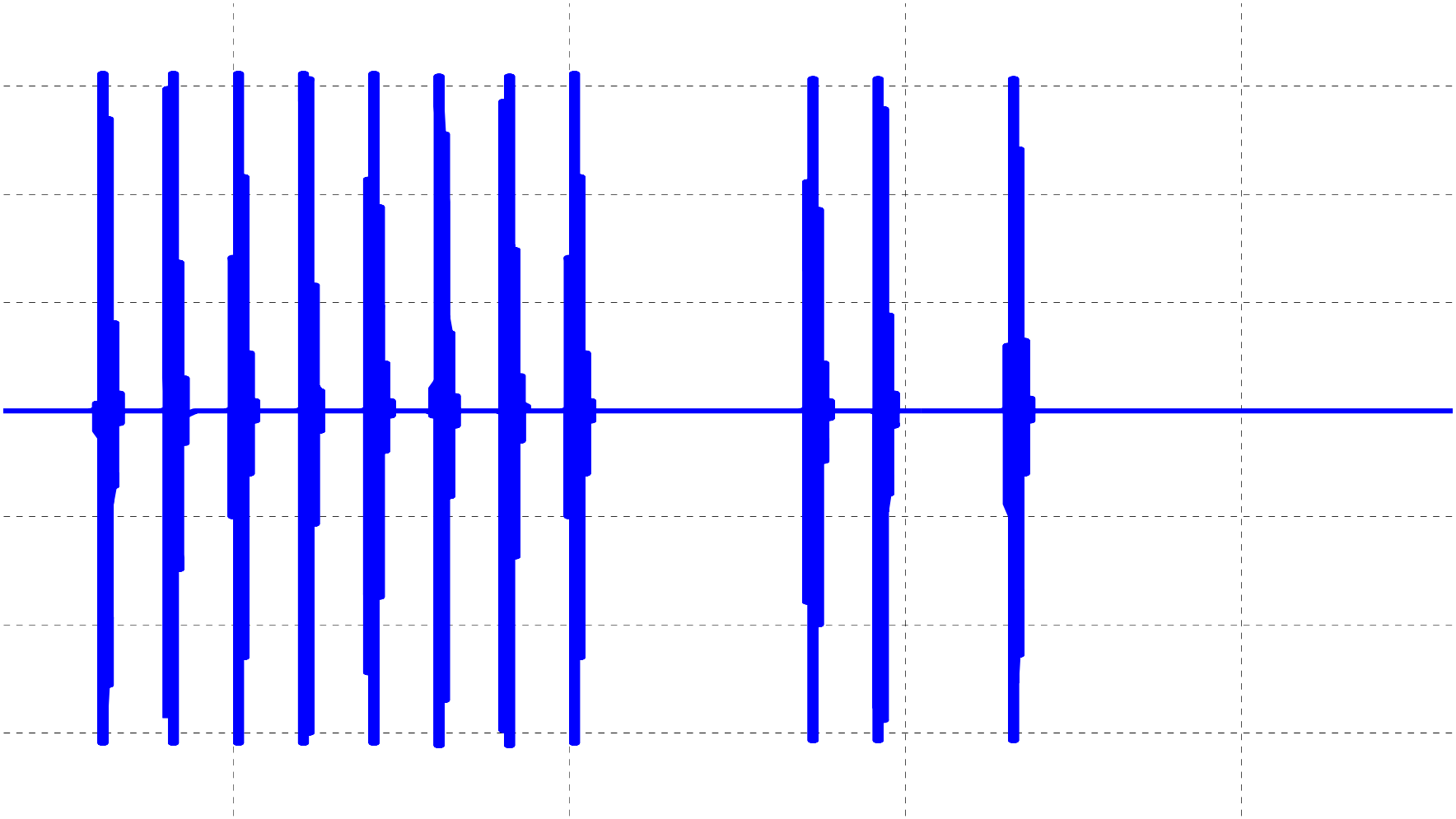
Pulse Amplitude Jitter



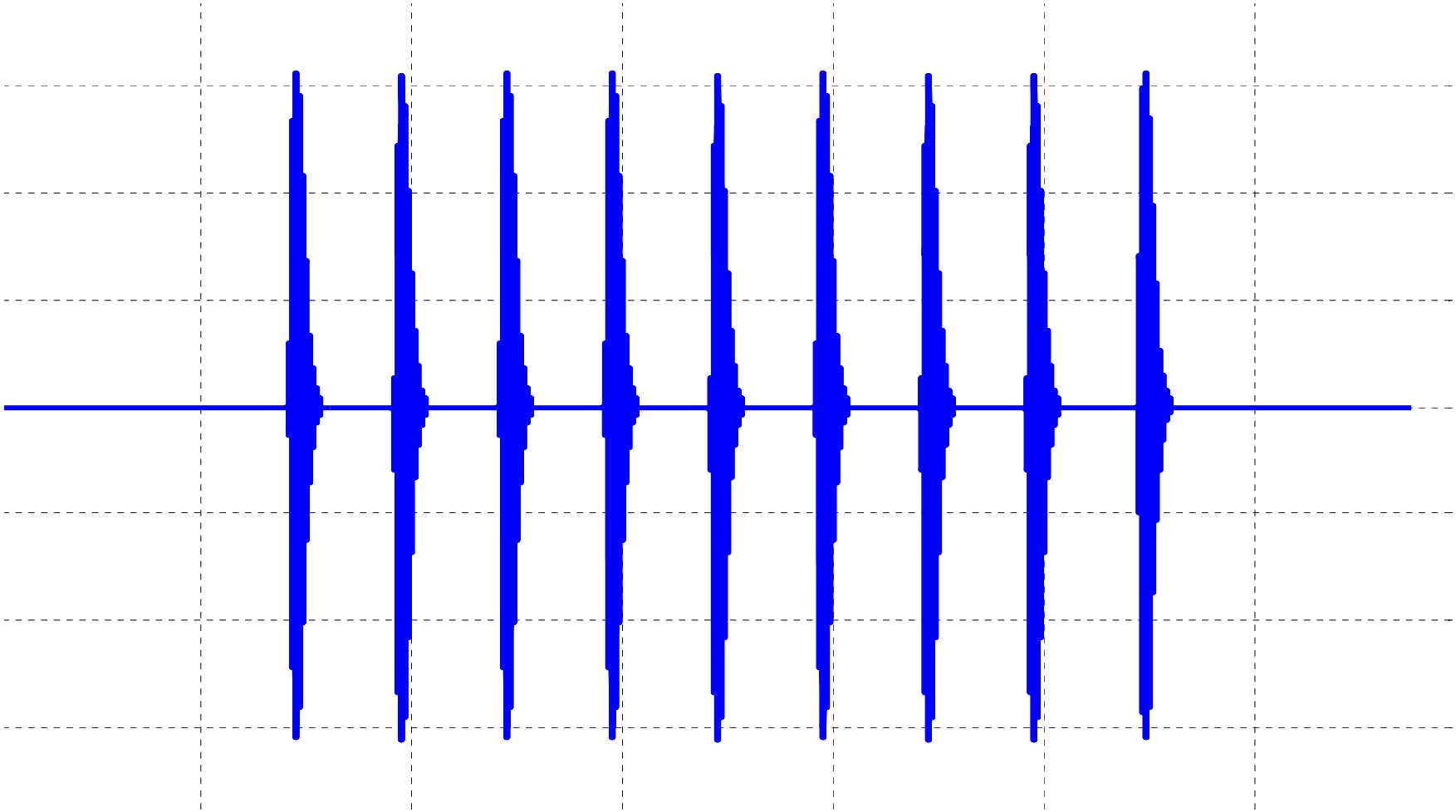
Pulse Timing Jitter (Exaggerated)



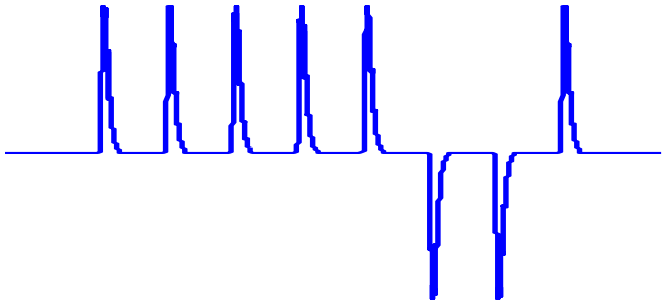
Blanking

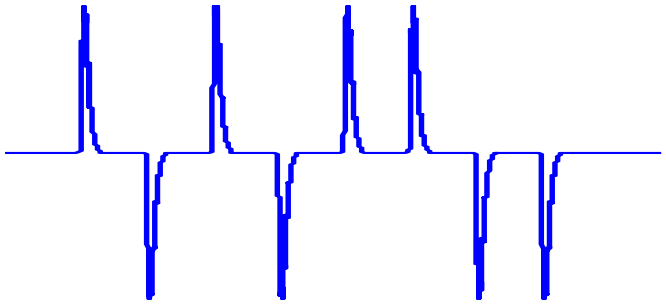


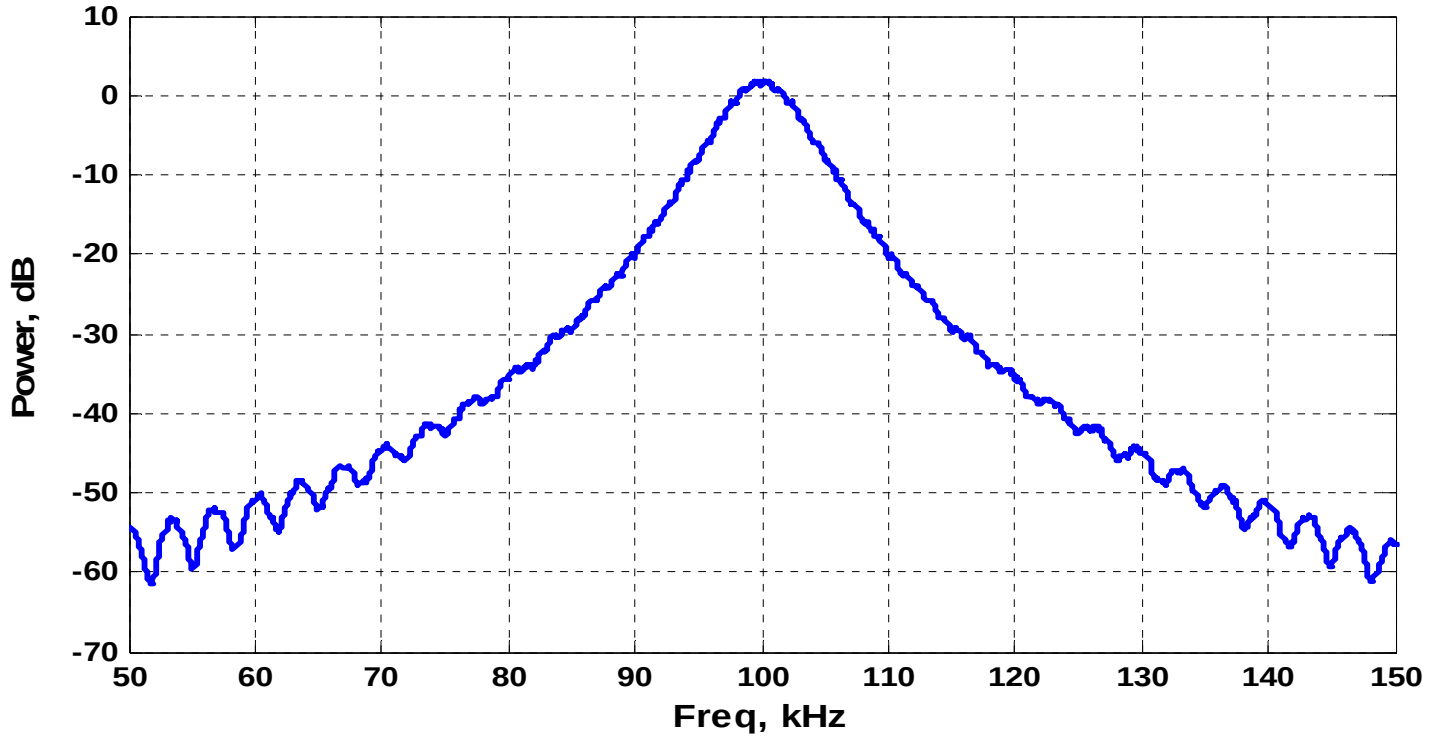
9th Pulse Modulation



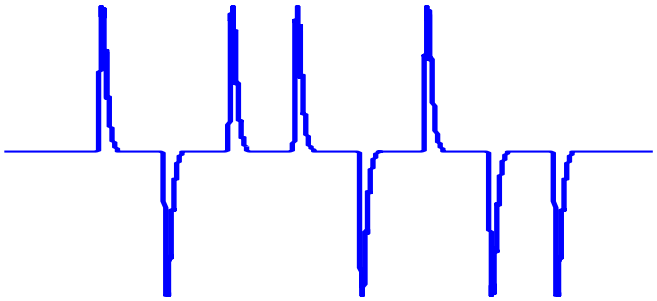
Current (Unbalanced) Phase Codes

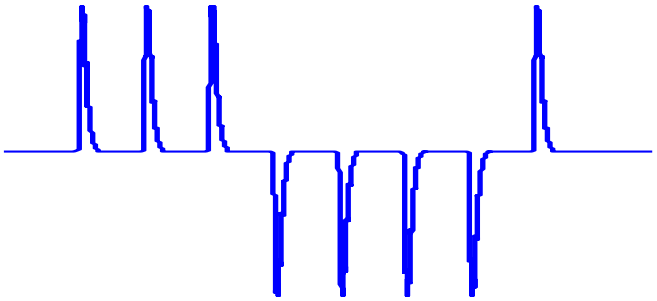


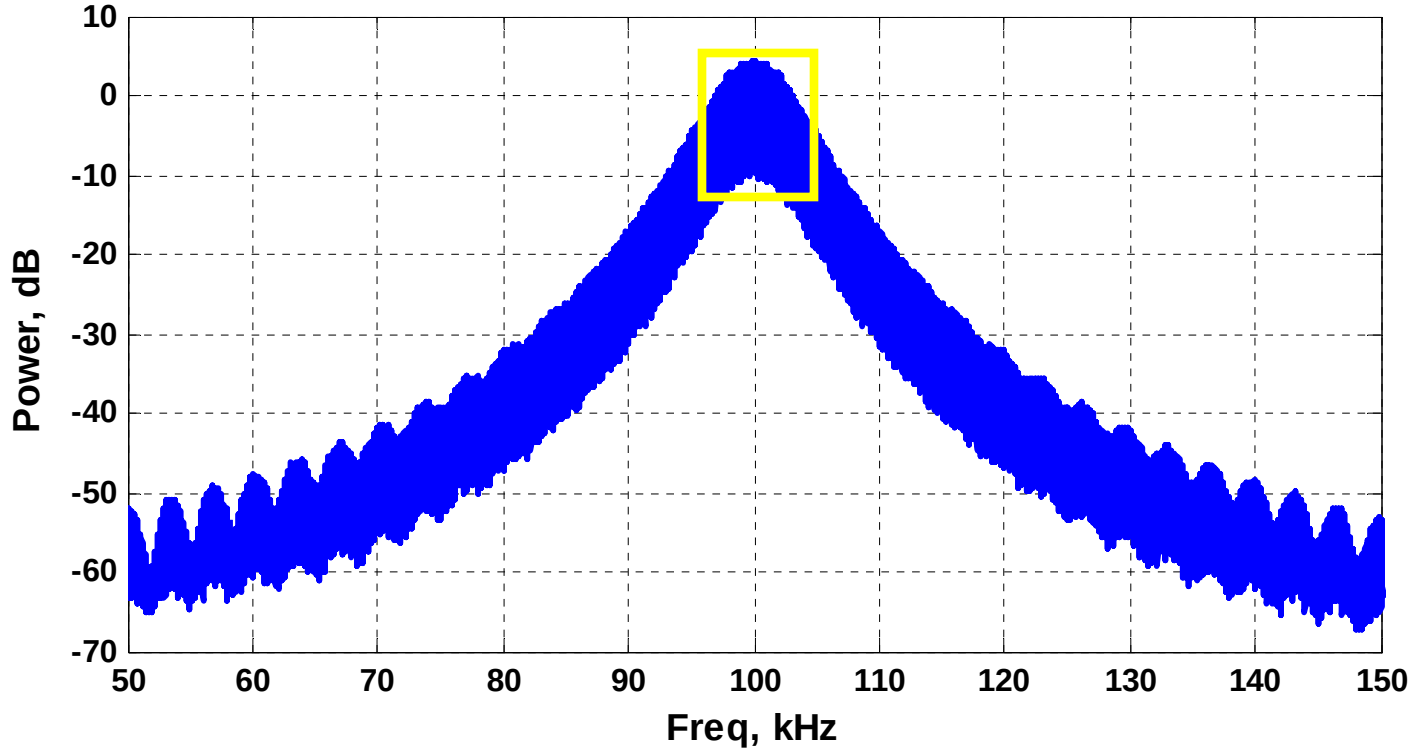




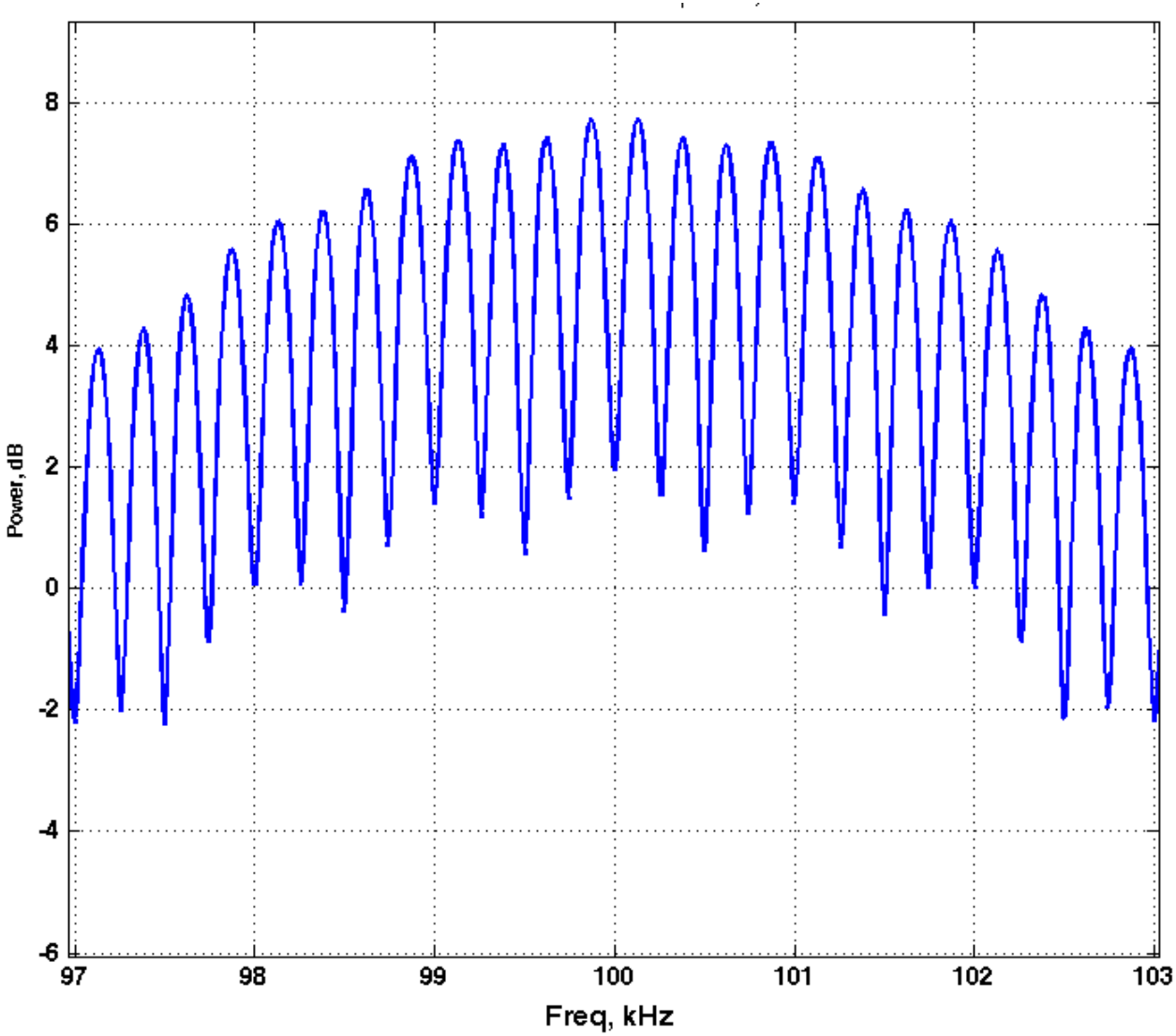
Example of Balanced Phase Codes



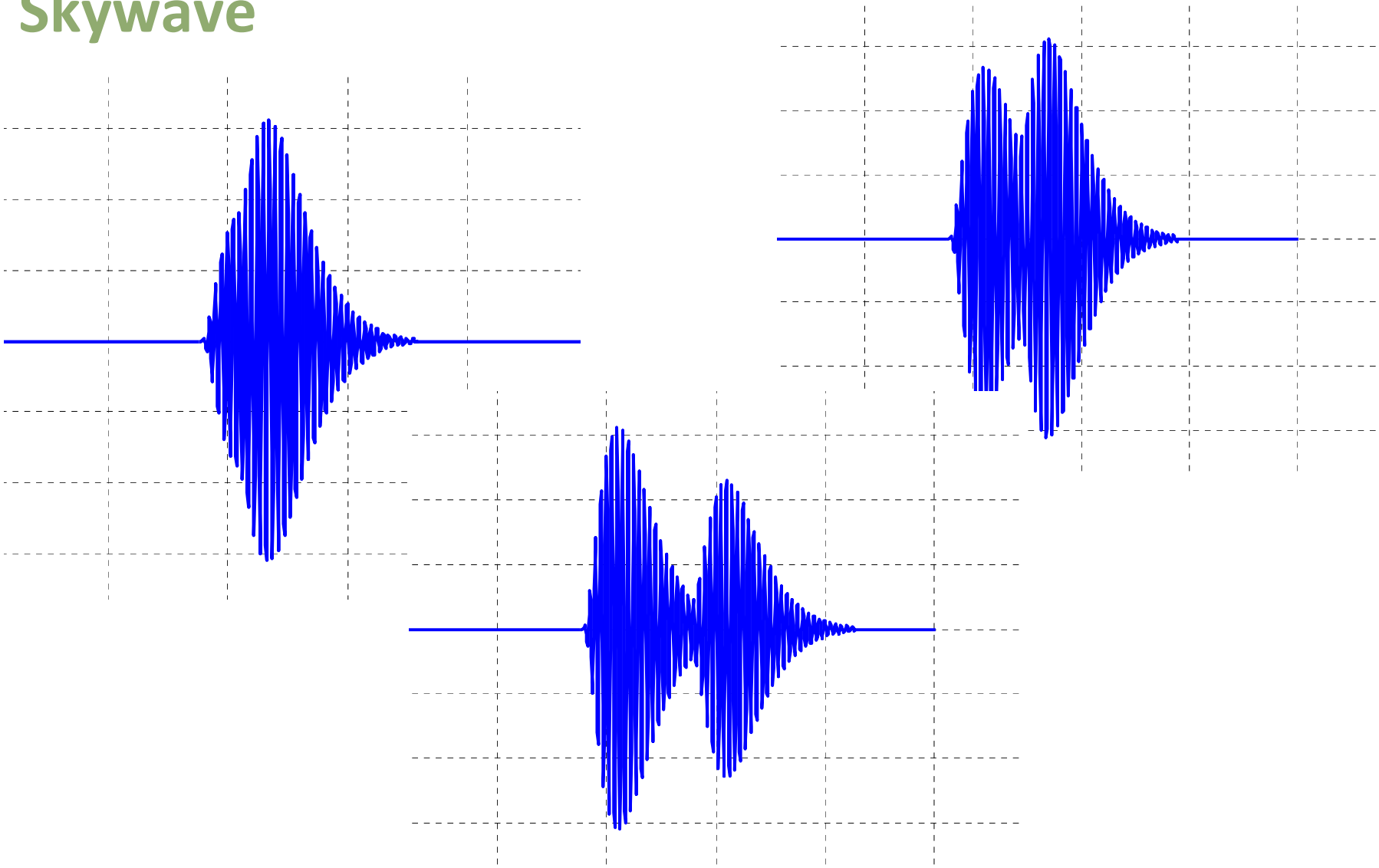




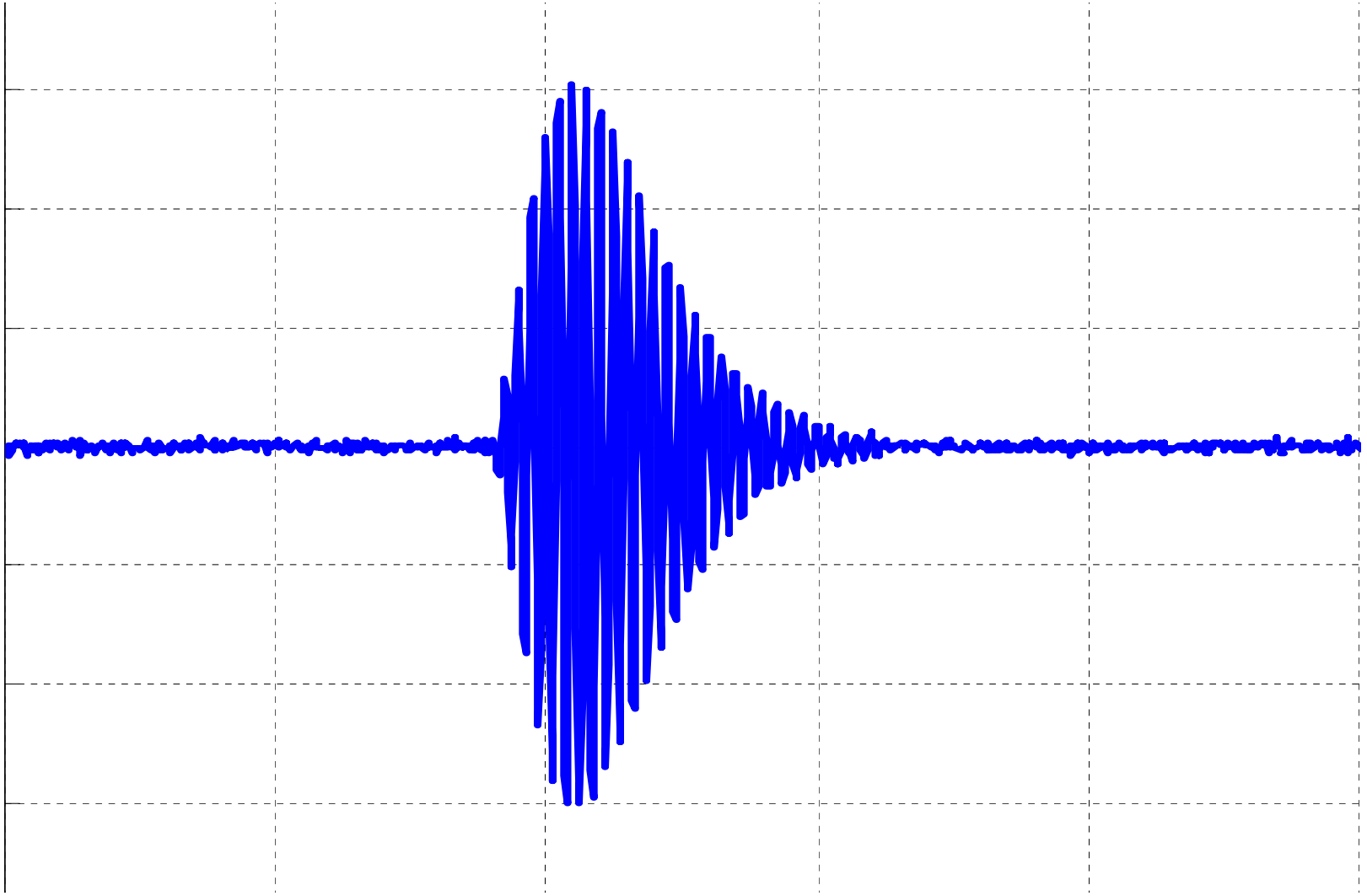
Close up of spectrum



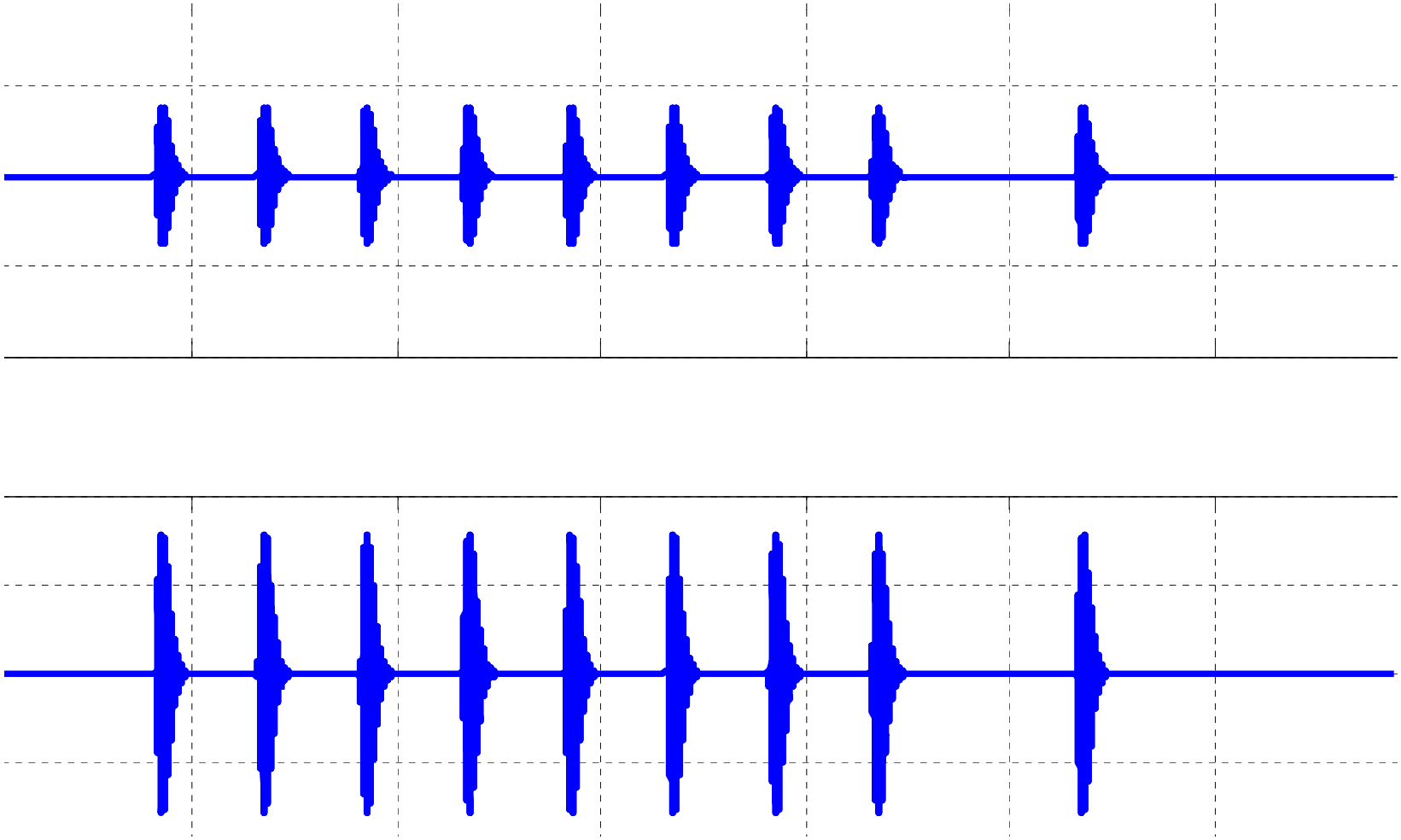
Skywave



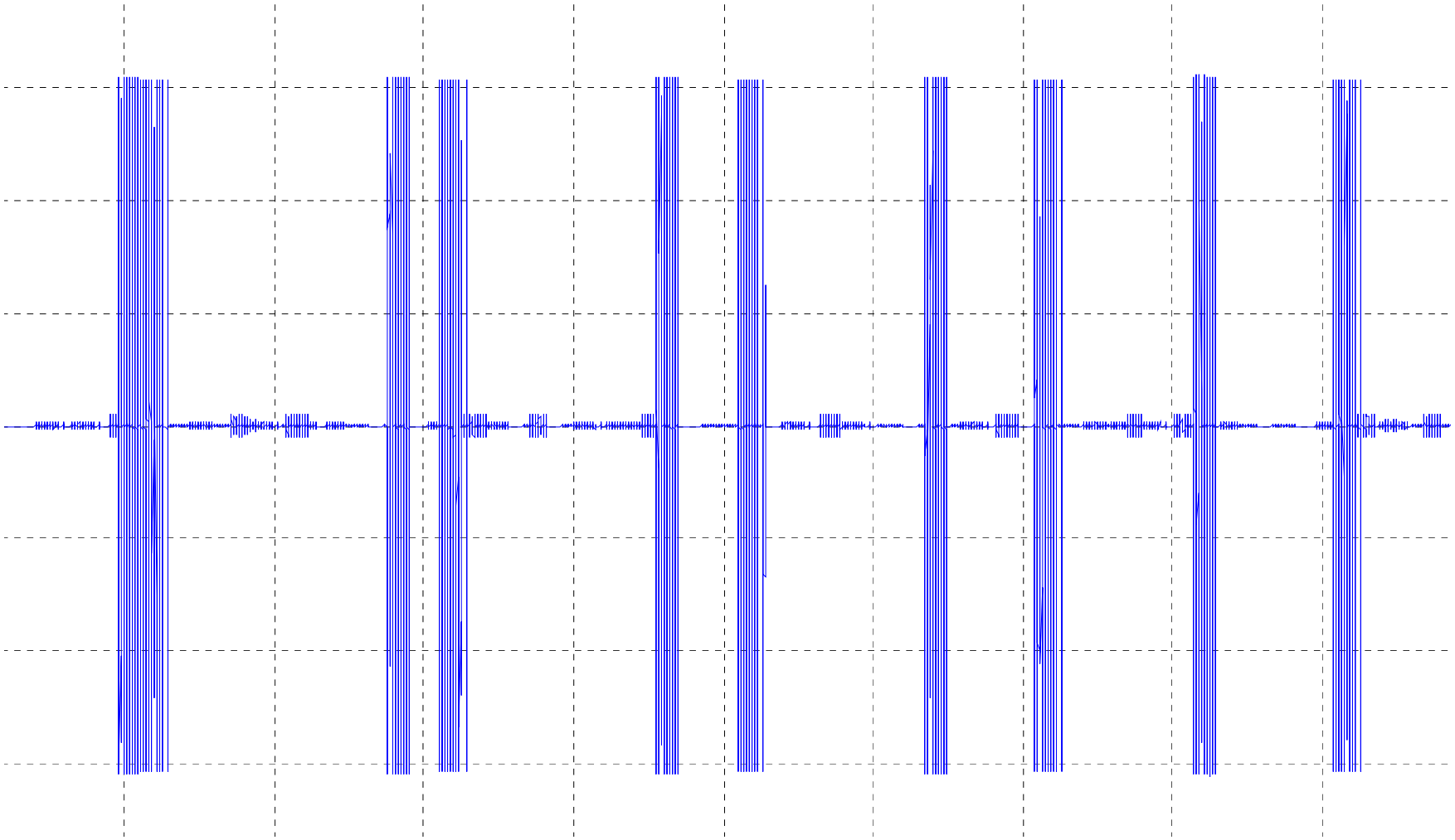
Noise



H-field Outputs



Combined (Multi-Chain)



Simulator Limitations

- **Lack of conductivity data**
  - **Canada**
  - **Europe**
  - **Etc**
- **Impacts ability to compute signal strengths and ASFs in non CONUS areas**
  - **CA stations are included but results may not be accurate**

The Loran Simulator 2.0

- Different LDC messages for each station
- Eurofix LDC
- Doppler shifts in TOAs due to vehicle velocity
- 1 PPS output
- Alternative propagation model for cases beyond existing grid
- Propagation grids for non-US towers
- Accurate time messages over LDC
- More complex skywave model
- Graphical User Interface
- On the fly system faults
  - Scenario time driven events (signals off air)
- Chayka?
- More noise options
  - Impulsive noise models
  - CW noise
  - P-static

Conclusions

- **We think eLoran is coming to a theatre near you**
- **See us at the booth for a demo!**

Questions?

gwjohnson@alionscience.com