


Improving Loran Coverage with Low Power Transmitters

PETERSON INTEGRATED GEOPOSITIONING

Sherman Lo, Benjamin Peterson, Kirk Zwicker, Per Enge

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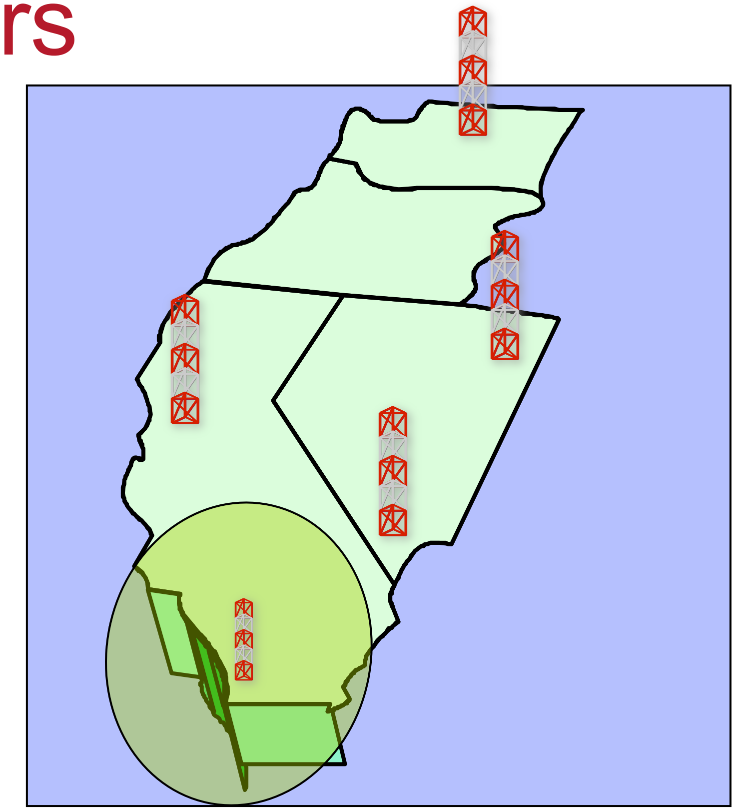
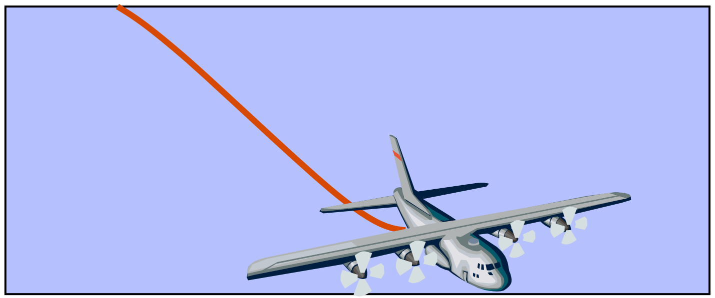
Reasons for Efficient, Low Power Transmitters

- Improved eLoran performance & coverage
  - Use existing assets w. shorter antennas
  - eLoran has higher requirements
  - Additional stations can help meet those requirements in more areas
- Tactical Loran
  - Carried aboard mobile platform
  - Prior talk

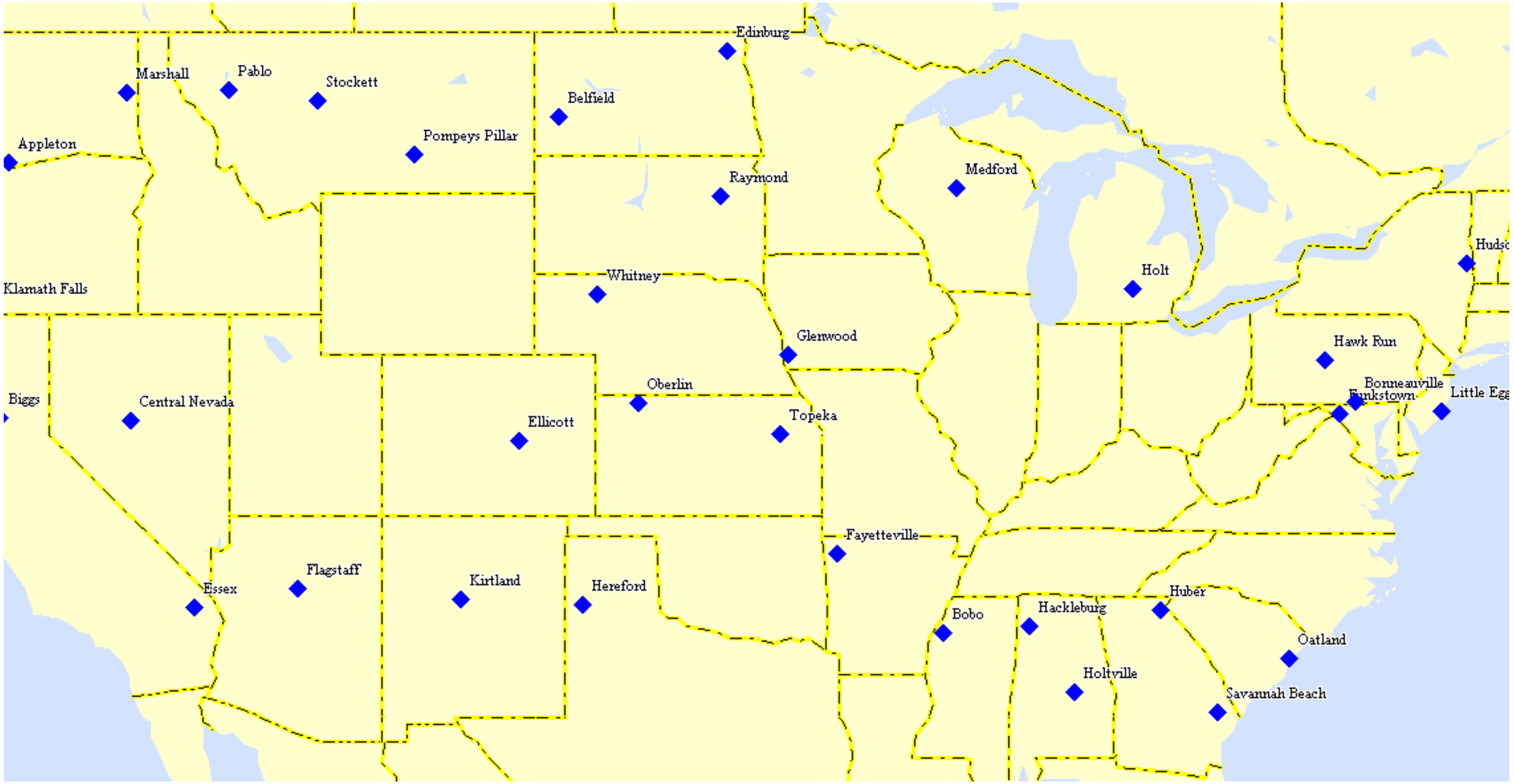




Benefits & Issues of Using Existing Assets

- Goal is to provide improved performance at low cost
- Many existing suitable towers around the world
- GWEN, DGPS sites in the US
  - Existing tower and building infrastructure
  - Many locations available – improved coverage in desired areas
- This talk …
  - Low power, efficient transmission
  - Feasible Loran compatible signals
  - Coverage benefits
    - Compatibility with Loran system configuration
    - Study configuration with most desirable benefits

GWEN Stations (Many, Not All)

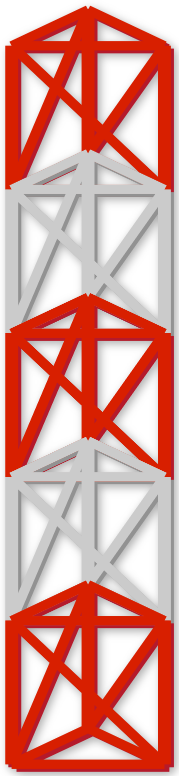


Transmitter Equipment

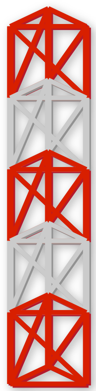
- Need efficient transmitter equipment for smaller antennas
  - Efficiency drives costs
- Use basic performance capabilities of Nautel transmitter as baseline
  - Transmitter design for improved efficiency
  - Energy recovery from antenna (vice damping)
  - At least 600 Loran ppm
- Nautel design should be capable of diplexing signal on DGPS with additions
  - Economics of design addition not assessed yet

Antennas & Performance

With signal design and/or higher duty cycles, range can be extended



Nominal Loran
625-1350 ft
400+ kW peak power
1000 km range



GWEN
299-306 ft
12.5 kW peak power
550 km range

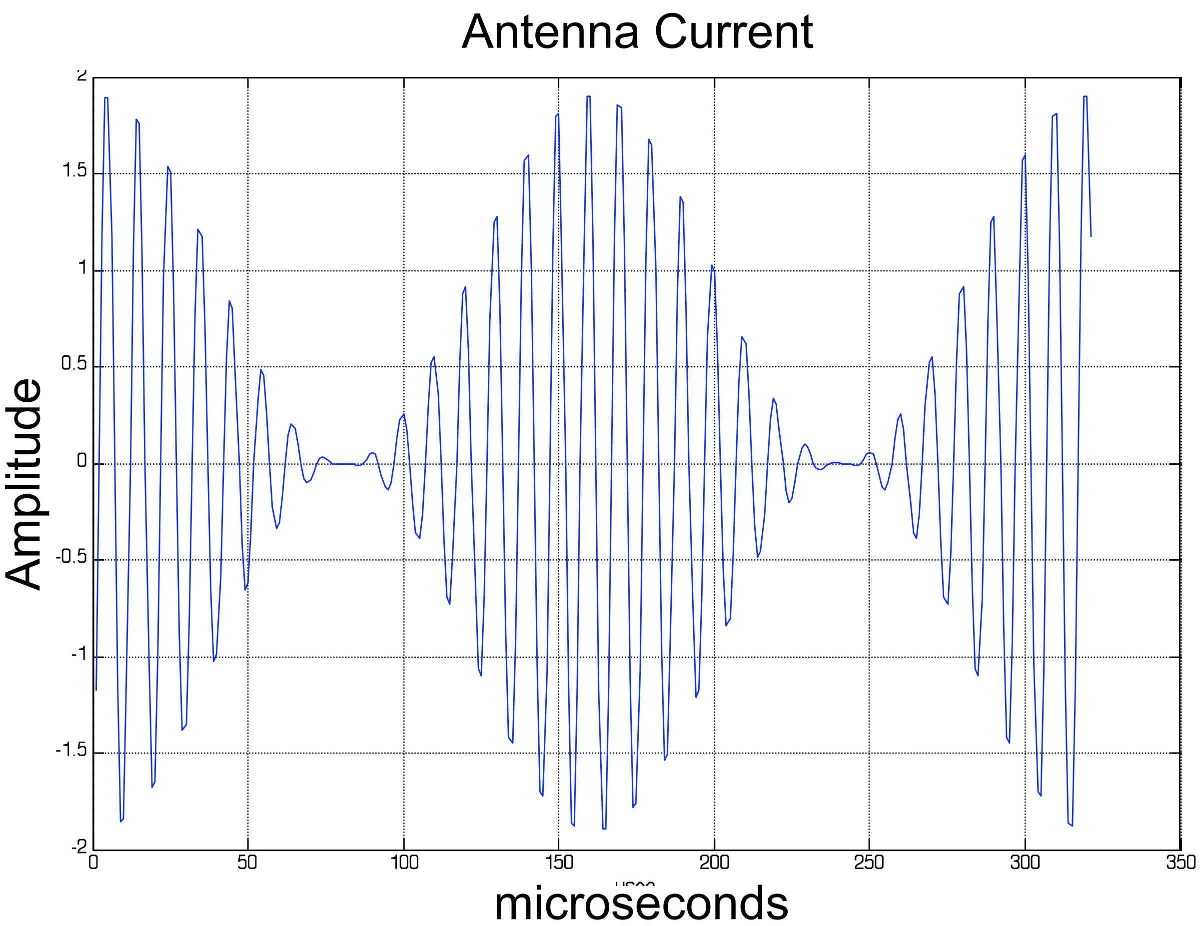
DGPS
150 ft or less
1.25 kW peak power
300 km range

Compatible Loran Signal

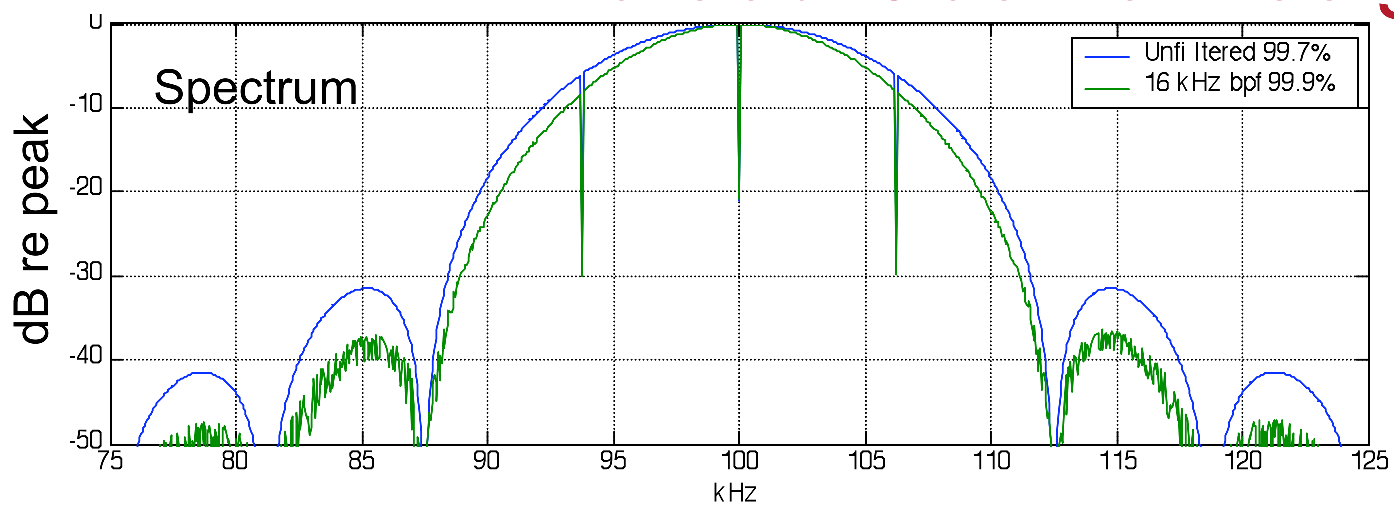
- Standard Loran signal may not be best
- Shorter range = less skywave
  - Skywave a prime driver of Loran signal design
  - Design signal with longer rise time and more dwell time at peak amplitude (narrower BW, more efficient)
  - Higher duty cycle also possible
    - More pulses for given time window
- Increased number of pulses per GRI (if it can be accommodated)
    - Longer time window
- Constraints
  - Spectrum
  - Transmitter limits on signal output, pulse/sec
  - Skywave

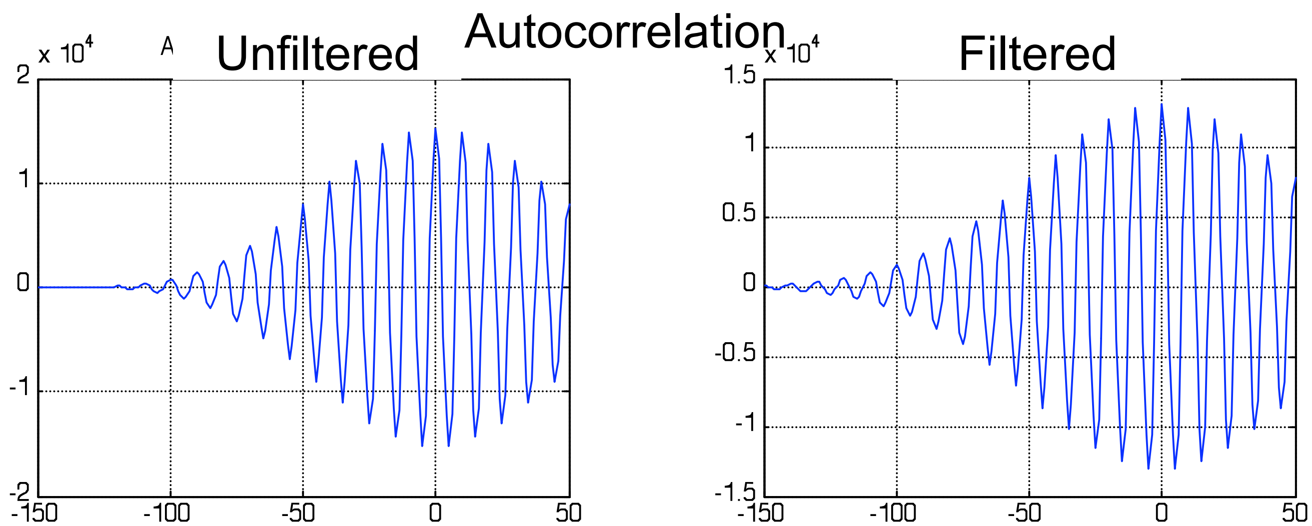
BPSK-Raised Cosine Signal

- Example: 6.25 kHz BPSK x Raised Cosine
- Phase shift in nulls
  – Easier for tx
- 20.48 ms in length
  – 128 pulses
  – Vs. 8-10 ms (1 pulse/ms) Loran



Spectrum & Autocorrelation of BPSK Raised Cosine Design



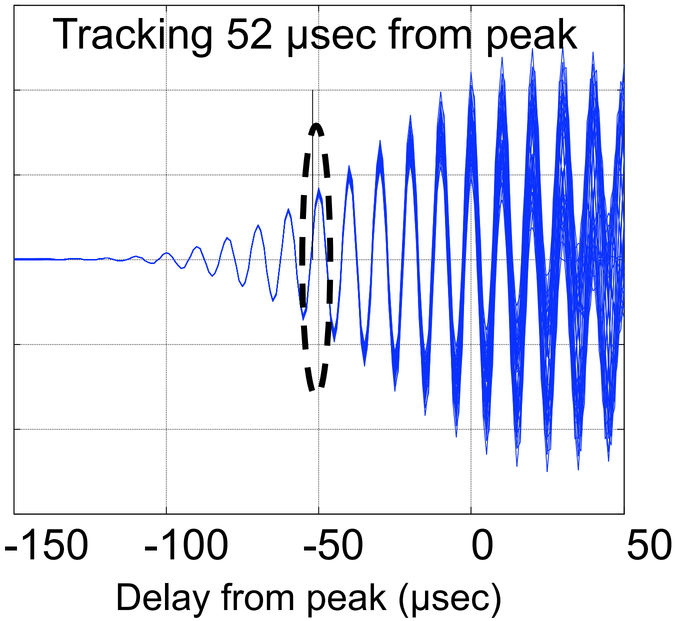


microseconds microseconds

- Unfiltered & 16 kHz filtered BPSK designs
- Both designs within spectrum
  - 99.7%, 99.9%
- Reasonable autocorrelation for navigation
  - similar to Loran
  - Reasonable for transmission equip to output

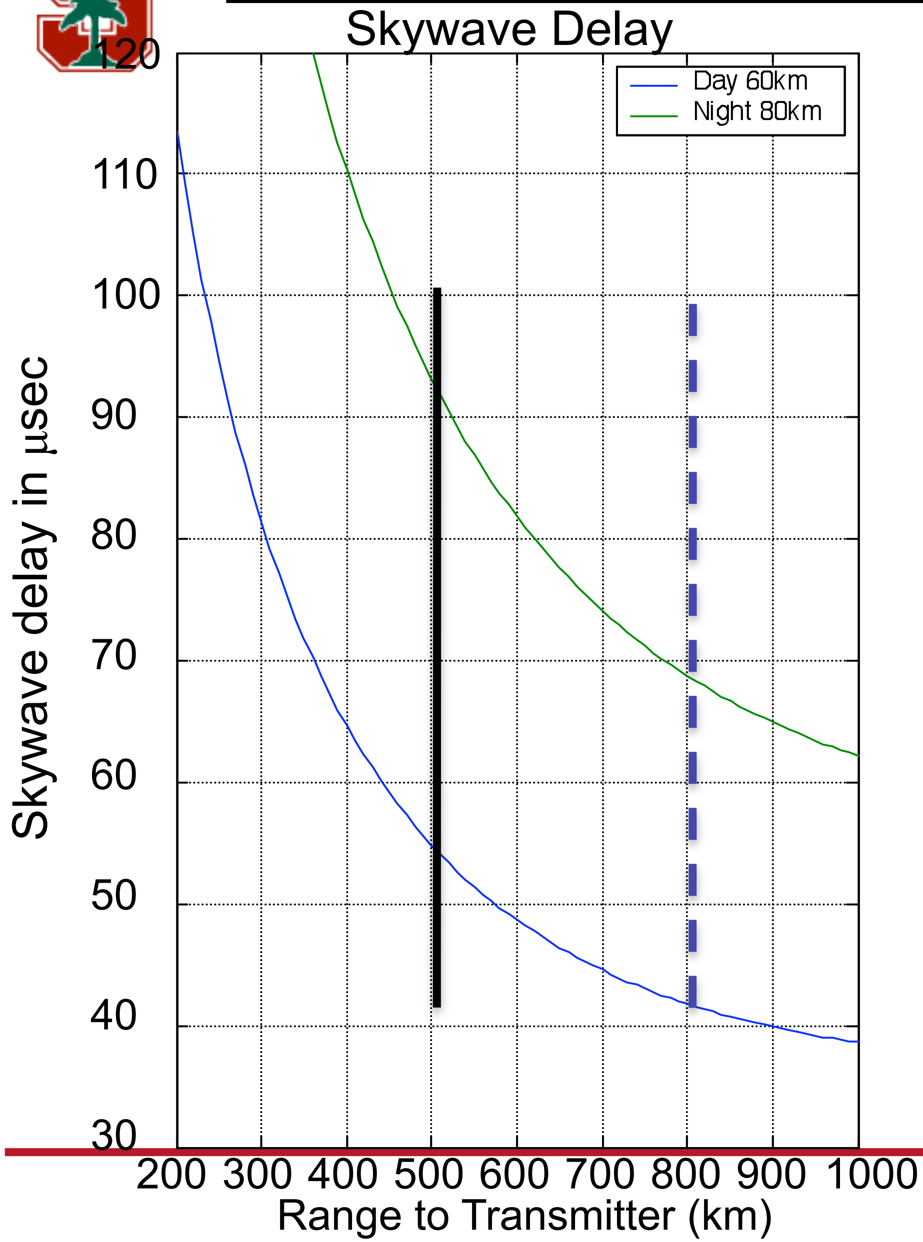
Nominal Performance of BPSK-RC vs. Loran

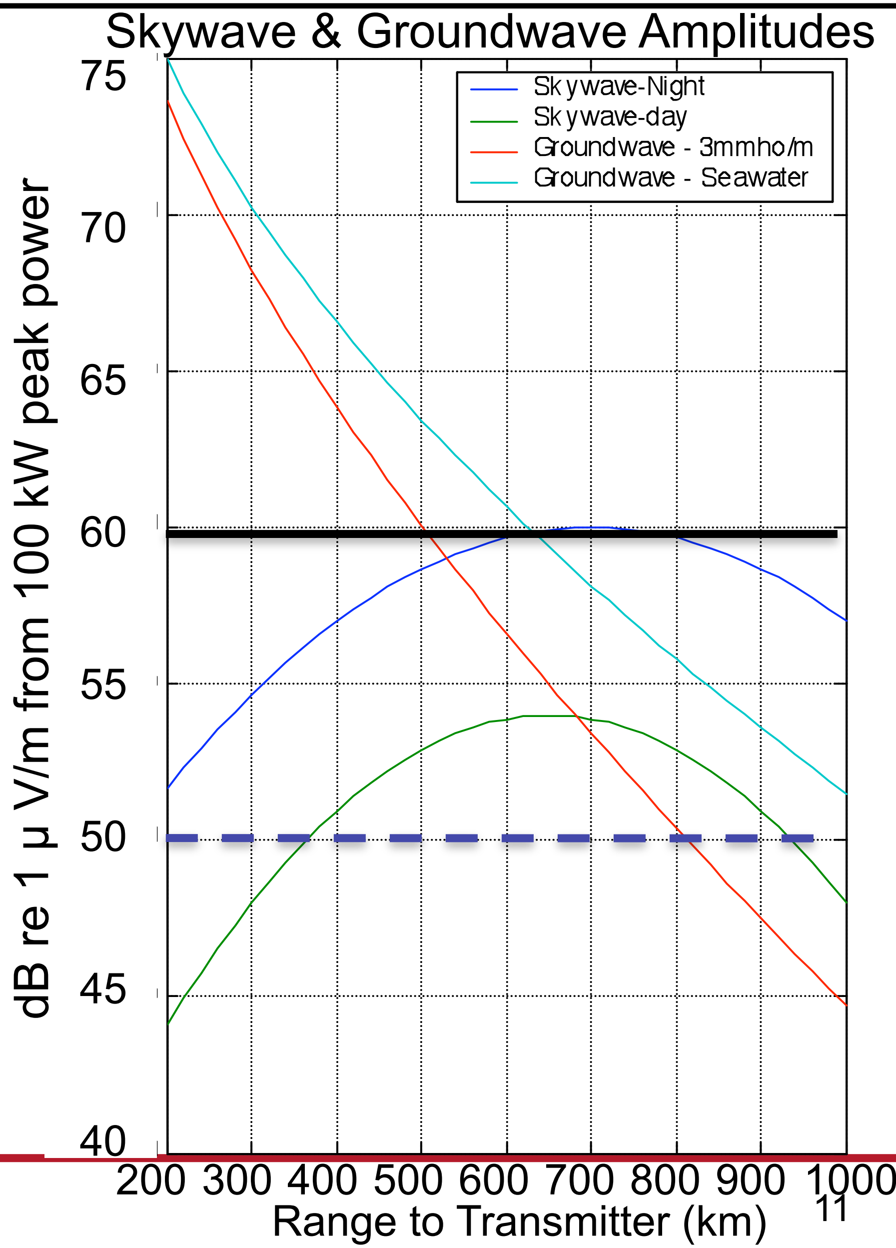
Tracking Pt. Re Peak	sigma TOA re Loran	sigma ECD re Loran	Equivalent Power Ratio	Normalized Power Ratio
-42 μs	0.166	0.329	36.4	14.2
-52 μs	0.213	0.423	22.0	8.6



Accounts for transmission length difference 20.48 ms (BPSK) vs 8 ms (Loran)

12.5 kW peak – 100 kW Equiv Loran 1.25 kW peak – 10 kW Equiv Loran



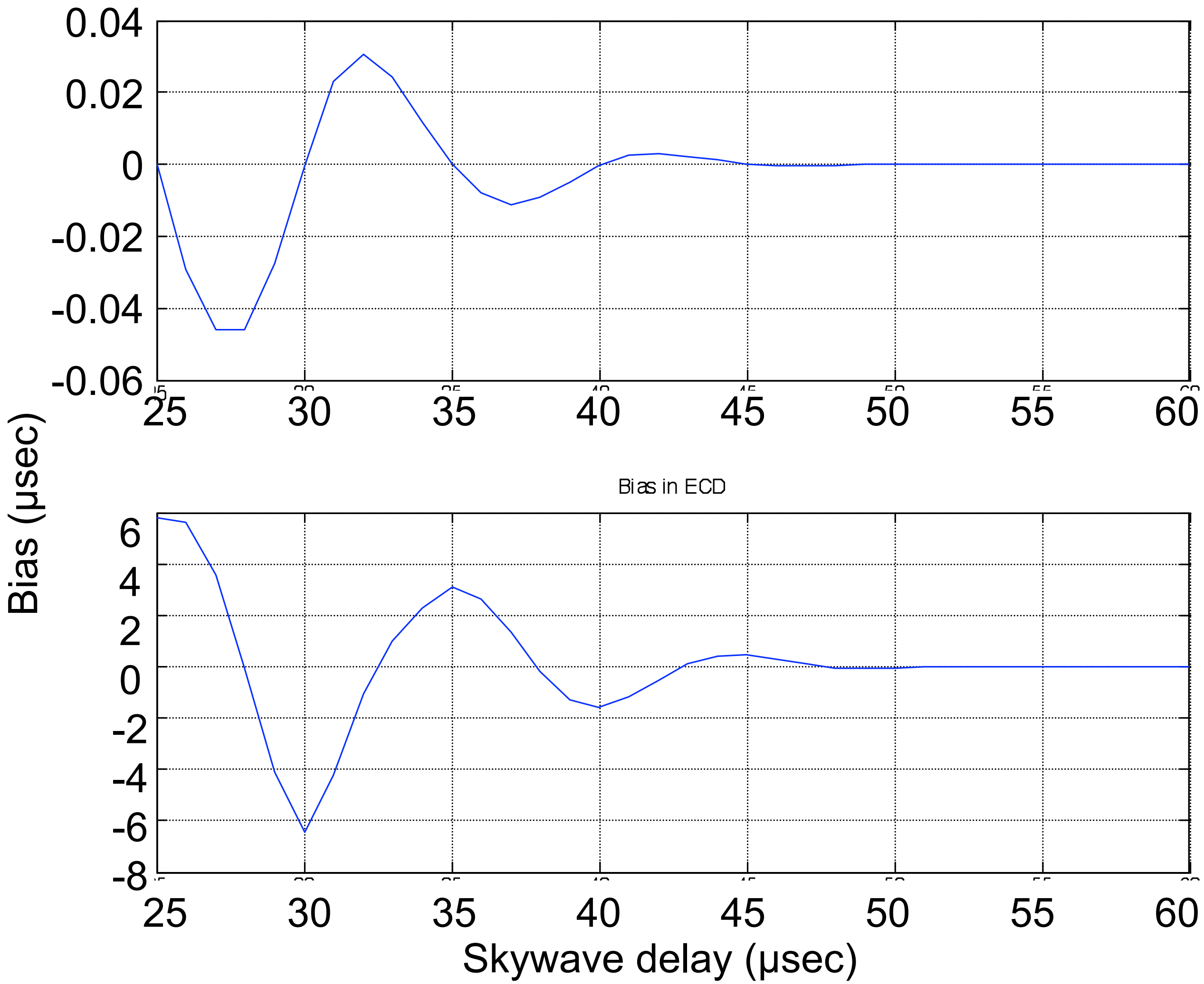


Skywave Assessment

	12.5 kW peak – 100 kW Equivalent Loran	1.25 kW peak – 10 kW Equivalent Loran
Range	800 km	500 km
Daytime		
Skywave delay	42 us	55 us
Skywave/Groundwave (SGR)	+3 dB	-10 dB
Nighttime		
Skywave delay	68 us	92 us
Skywave/Groundwave	+10 dB	-1 dB

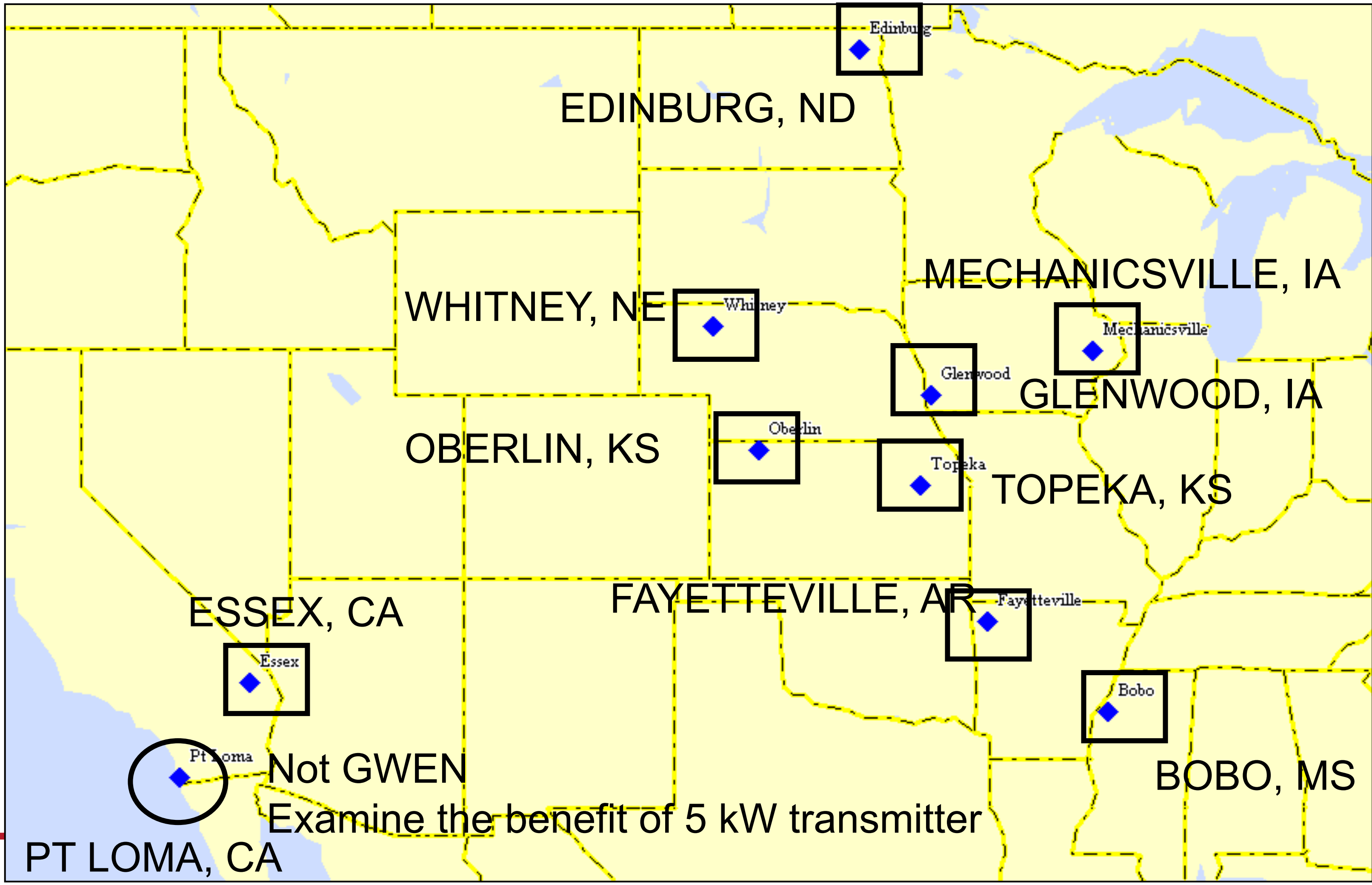
(Assuming 3mmhos/m & sig strength of 50 dB re 1 uv/m)

Phase & ECD Bias, SGR = 0 dB RF Tracking (30 μsec from peak)



- RF Tracking at zero crossing
- Tracking 30 μsec from peak
  - Power -3.2 dB
  - Maximum bias ~ 15 m in phase
  - ECD bias worse

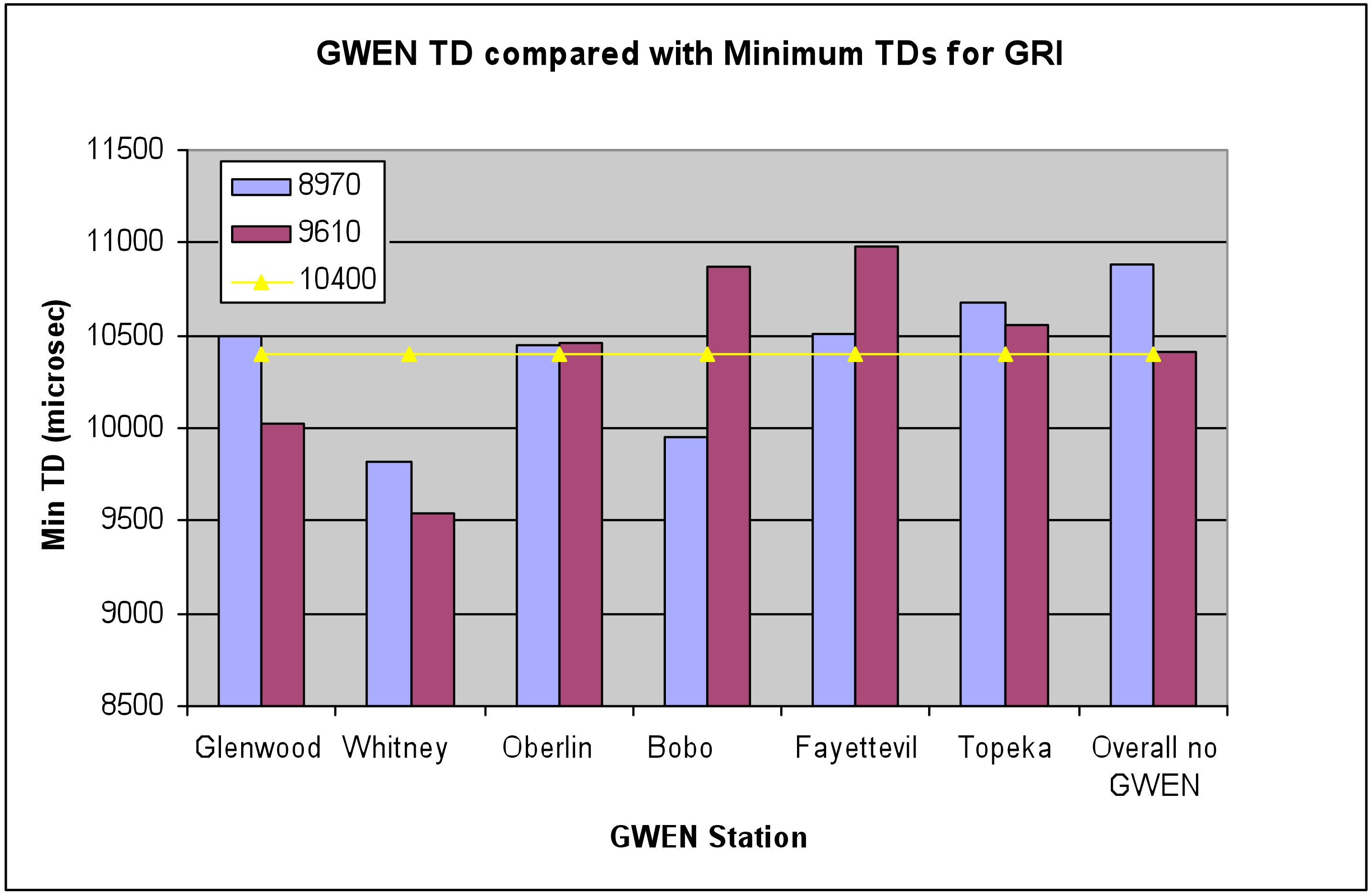
GWEN/DGPS Sites Examined



Coverage Benefits

- Coverage Benefits of Using GWEN/ DGPS
  - 50 kW GWEN, 5 kW DGPS
- Fit low power tx within Loran system
  - Existing GRI
  - Maintain minimum TD
- Use US as case study
  - Minimum TD is 10411 (spec is 9900)
- Examine different feasible configurations

Minimum TDs with the addition of a GWEN station



Need to fit within current Loran chain architecture

Using GWEN Stations

Chain	Number	GWEN sites
8290	1	Edinburg, ND, Whitney, NE
8970	1	Glenwood, IA; Oberlin, KS; Fayetteville, AR; Topeka, KS
9610	1	Oberlin, KS; Bobo, MS; Fayetteville, AR; Topeka, KS

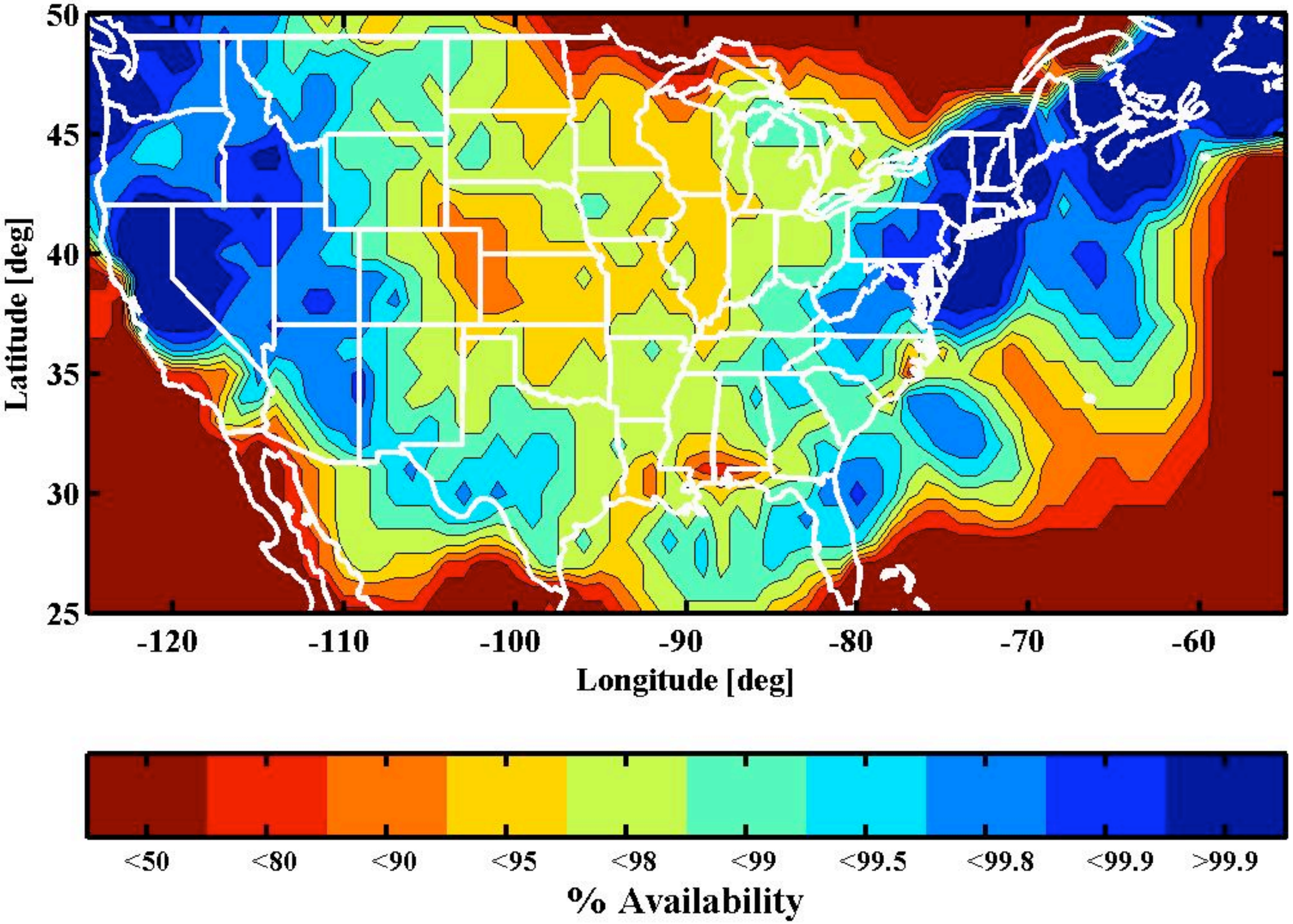
- Can add up to 3 stations to the Midwest
- Can add up to 3 stations on West Coast (9940) or have extended pulse sequence on fewer stations
- Cannot add station to S. Florida without new chain or shorter pulse sequence

Test Scenarios

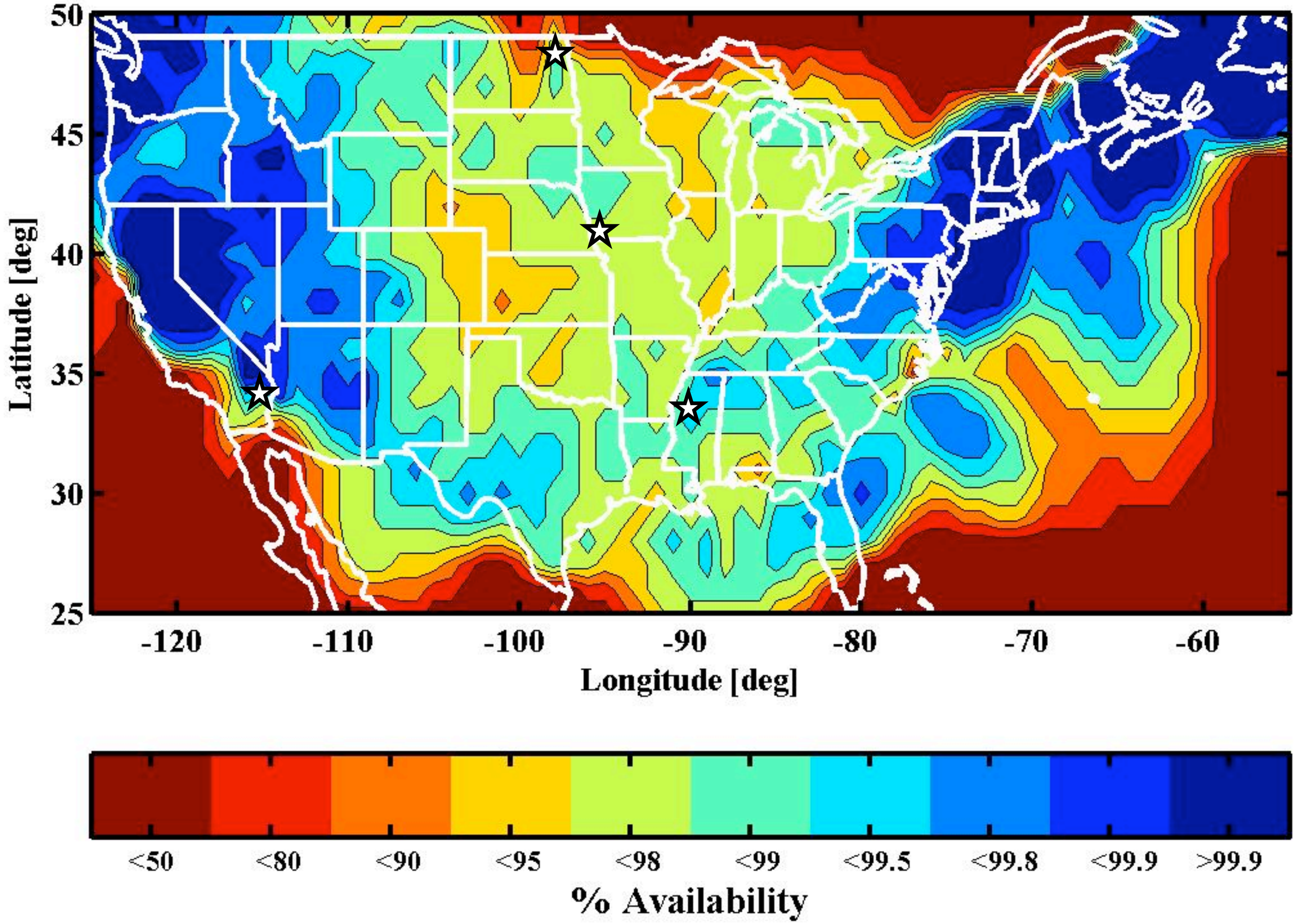
Scenario	7980	8290	8970	9610	9940
1	---	Edinburg	Glenwood	Bobo	Essex
2	---	Edinburg	Oberlin	Bobo	Essex
3	---	Edinburg	Glenwood	Fayetteville	Essex
4	---	Edinburg	Glenwood	Oberlin	Essex
5	Miami	Whitney	Glenwood	Bobo	Point Loma
6	Key West	Whitney	Glenwood	Bobo	Essex

- Scenarios 1-4 focus on Midwest coverage
- Scenario 5,6 examines S. California & Florida
  - Difference previous scenarios for benefits of Pt. Loma vs. Essex
  - Difference between Miami & Key West

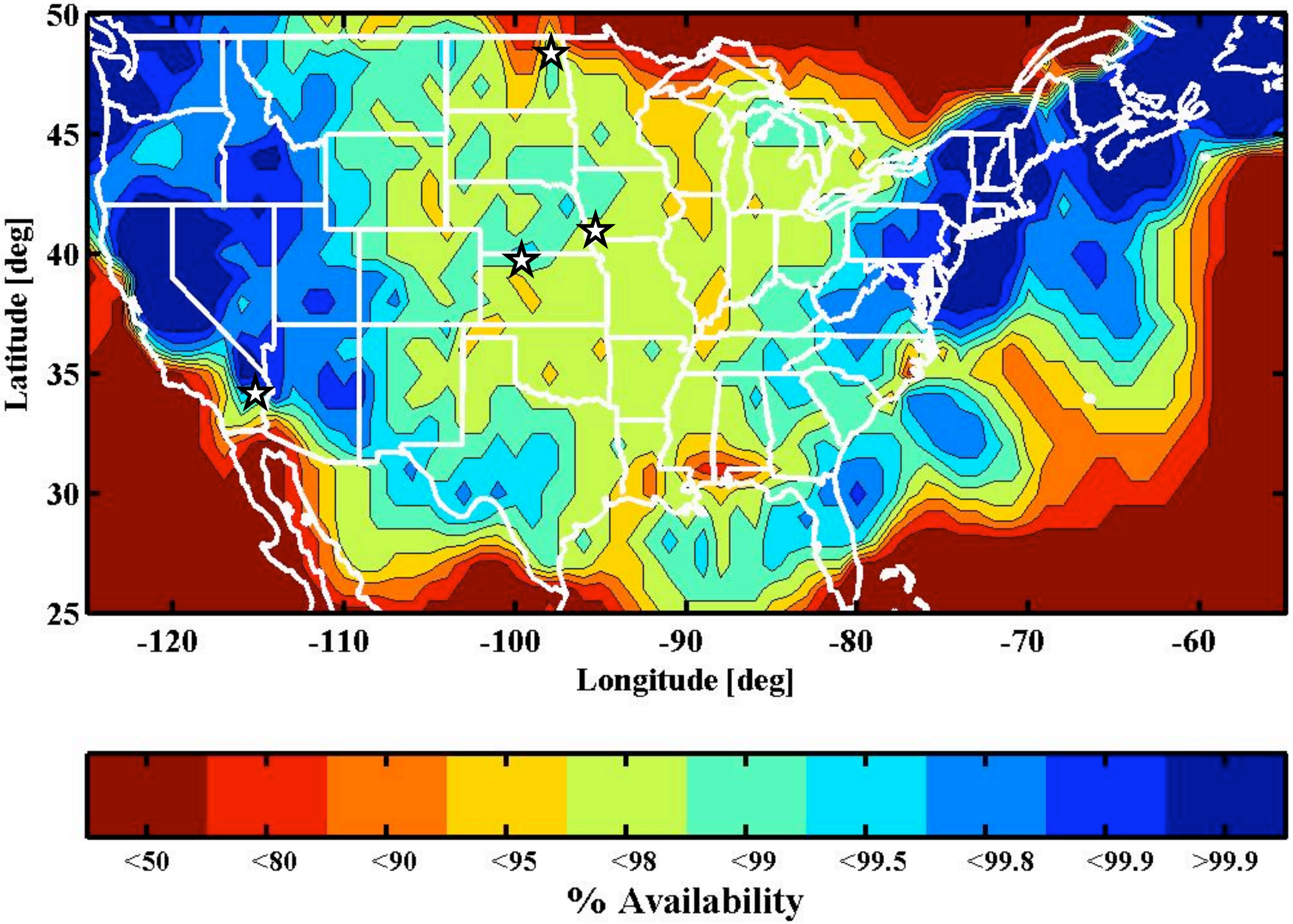
Nominal Non Precision Approach (NPA) Availability



Scenario 1 Availability



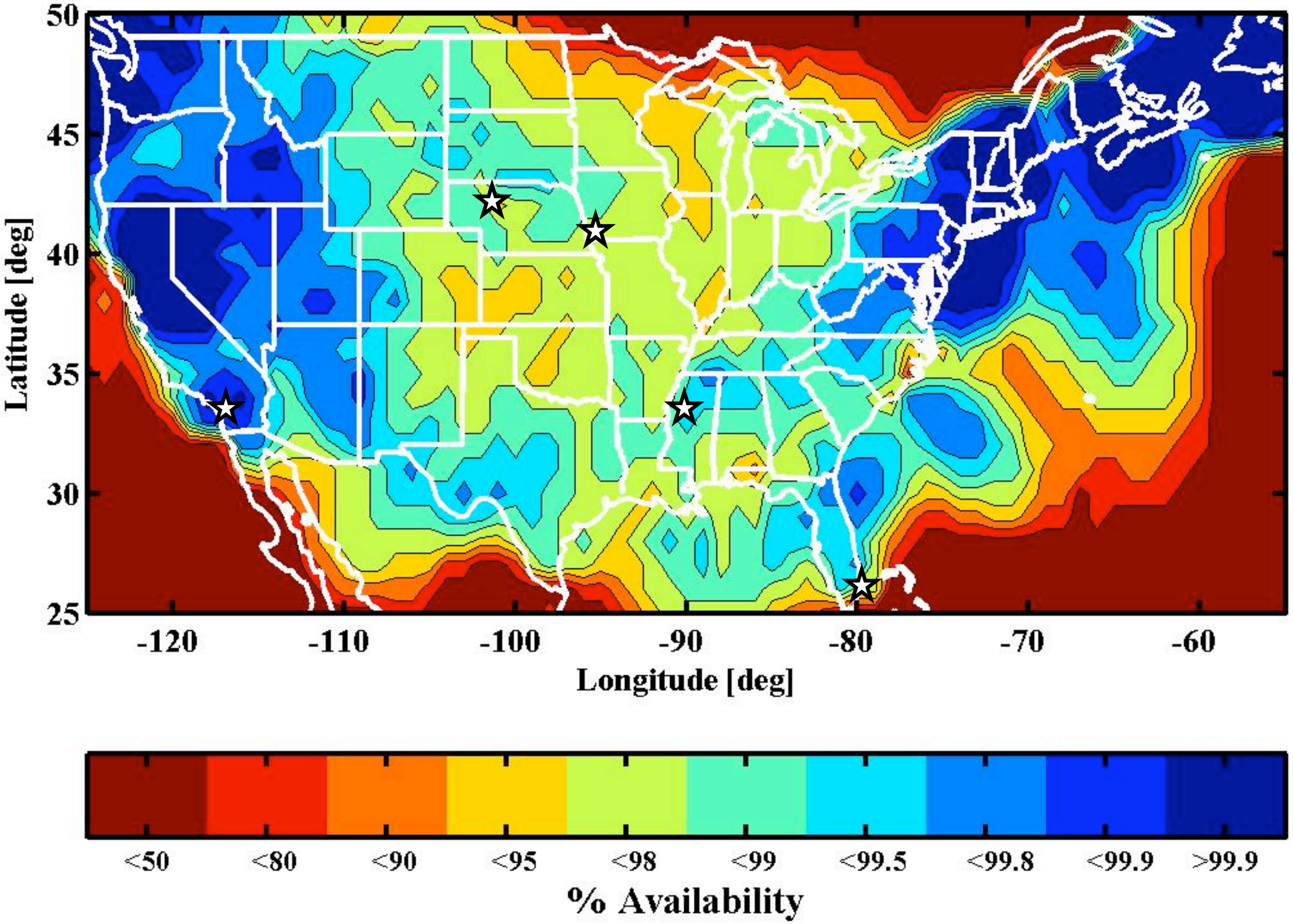
Scenario 4 Availability



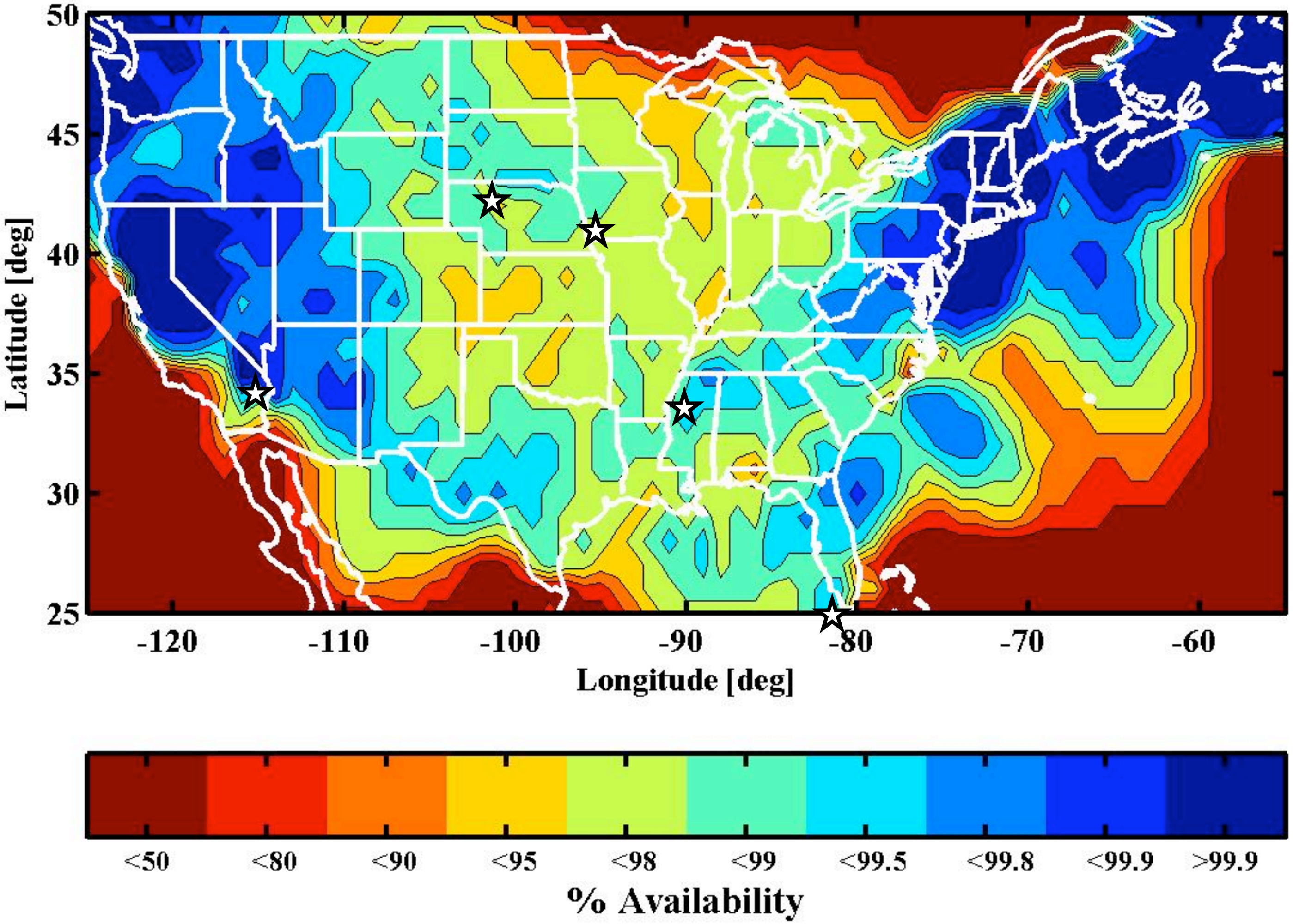
How much can we benefit from additional smaller transmitters?

- Would having 5 kW transmitters be useful?
  - Perhaps at DGPS sites
  - Point Loma (near San Diego), Miami or Key West
- Which is preferable: Point Loma at 5 kW or Essex at 50 kW?
- Which is preferable: Miami or Key West?

Scenario 5 Availability



Scenario 6 Availability



Summary

- Newer transmitter technology can enable Loran transmission using smaller antenna
  - Low power, more efficient transmitter equipment
- Signal design can improve range performance
  - Non standard Loran
- Current chain configurations allows us to add 3 GWEN stations to Midwest and 1-3 to West Coast
- Geometry is very important
  - Lower power station in San Diego is better than high powerinland
- Results vary somewhat depending on which ASF model is used but there are noticeable improvements
  - > 90% for 2004 Report Noise Model
  - > 95% for Revised Noise Model (Pessimistic result)

Acknowledgments & Disclaimer

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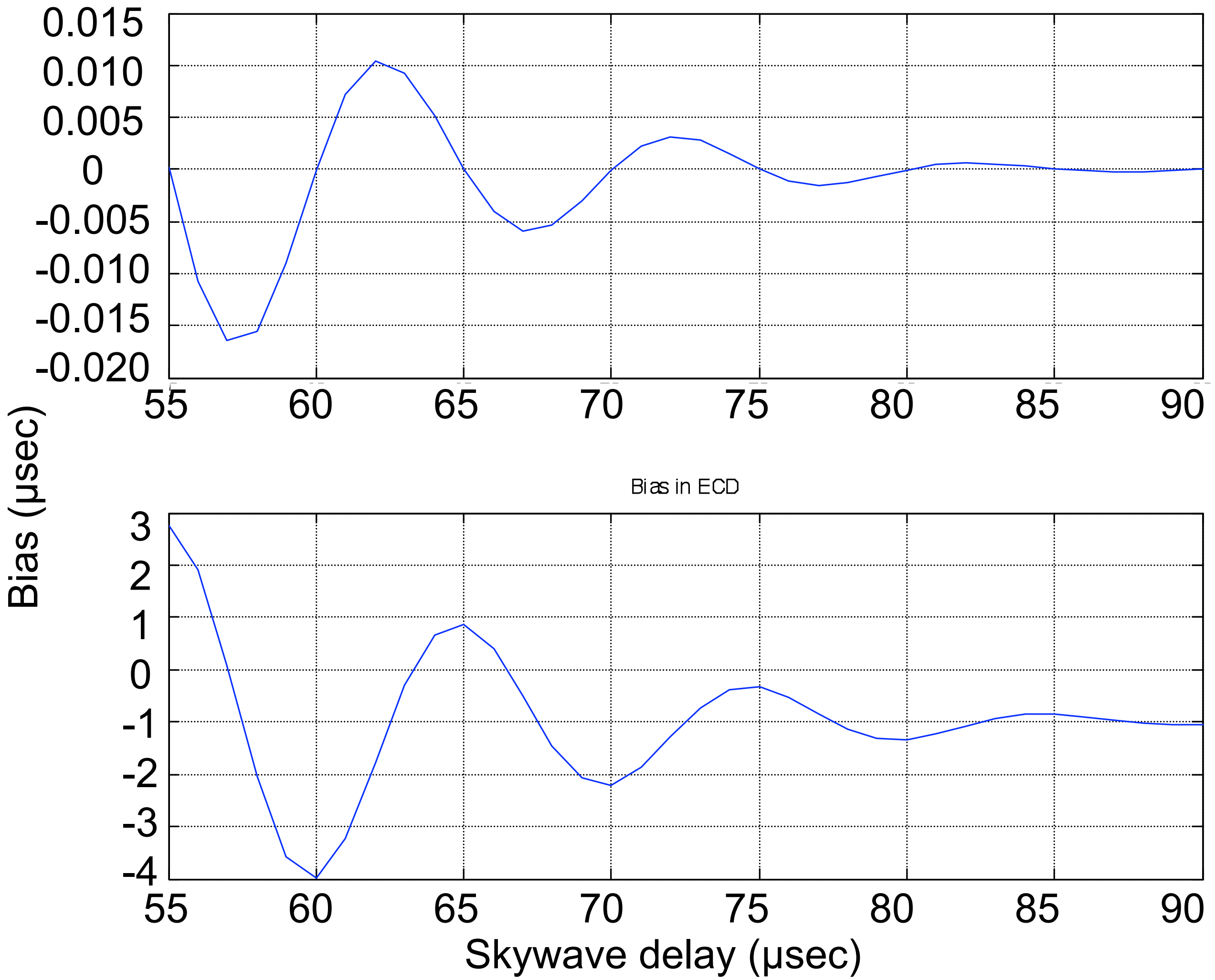
- The LORIPP & Nautel
- The views expressed herein are those of the authors and are not to be construed as official or reflecting the views of the U.S. Coast Guard, Federal Aviation Administration, Department of Transportation or Department of Homeland Security or any other person or organization.

Phase & ECD Bias, SGR = 0 dB

Correlation Tracking (52 μsec from peak)



- Correlation Tracking
- Tracking 52 μsec from peak
  - Power -5.2 dB
  - Maximum bias ~ 5 m in phase
  - ECD bias worse