
eLoran TOA Measurement System 2.0

- System Enhancements, Validation and Shakedown -

Wouter Pelgrum – EXIAN Navigation Solutions

Arthur Helwig – Reelelektronika B.V.

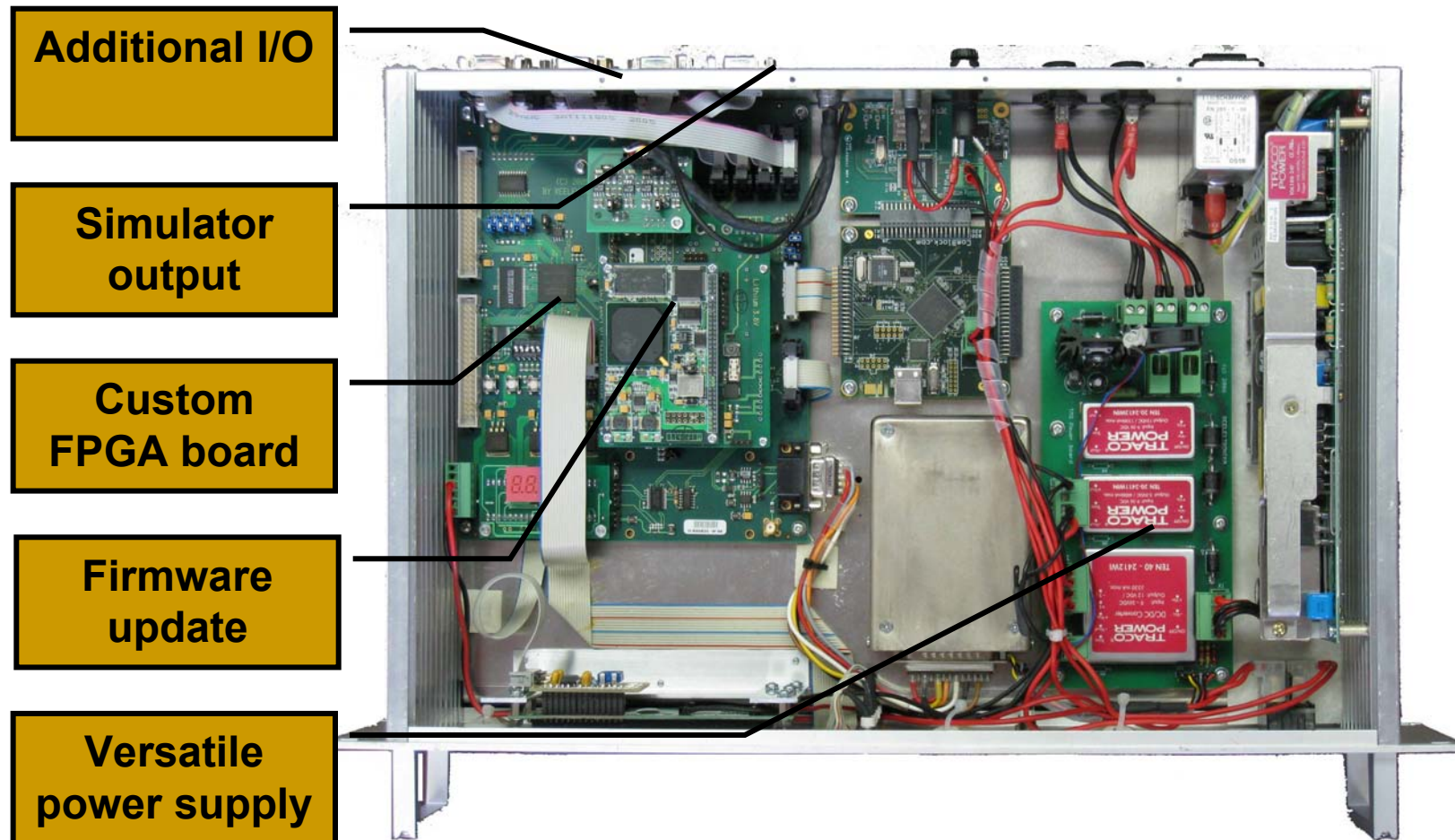
David Diggle – Ohio University

Mitchell Narins – US Federal Aviation Administration

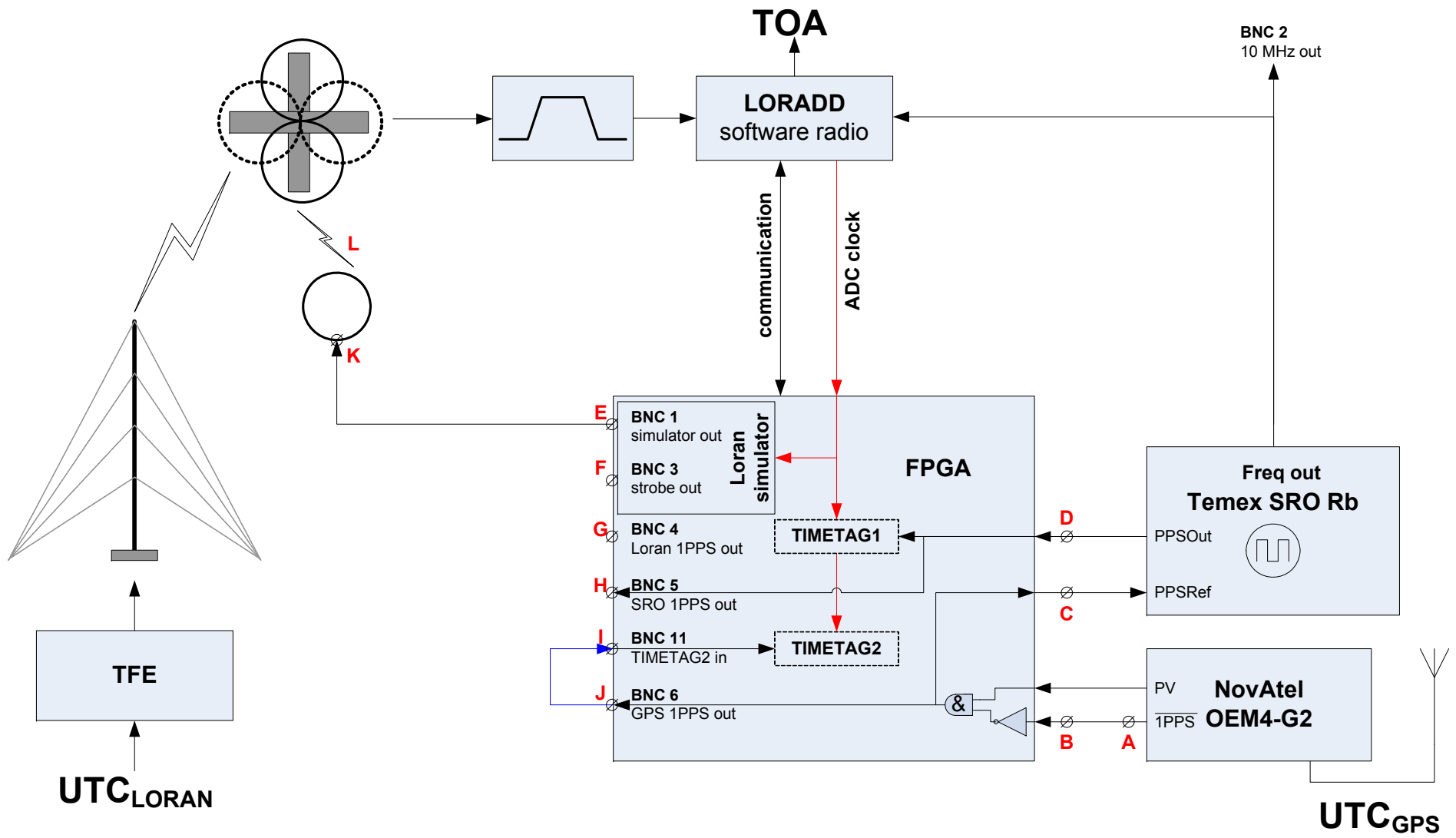
International Loran Association, 36th Annual Convention and Technical Symposium
October 16-17 2007, Orlando, FL, USA

Reelektronika TMS 1.0 → 2.0

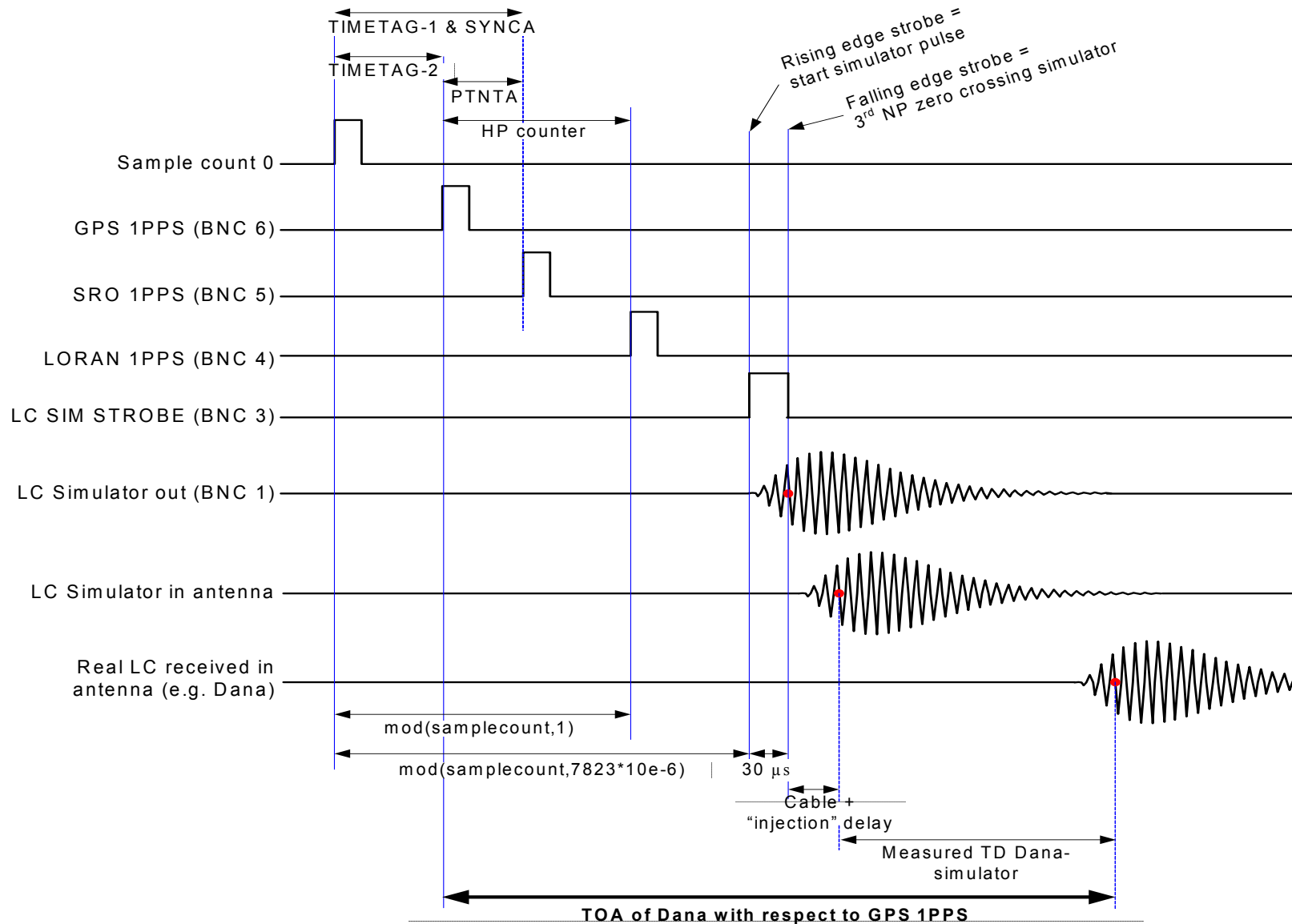
From prototype to product



Reelektronika TMS timing



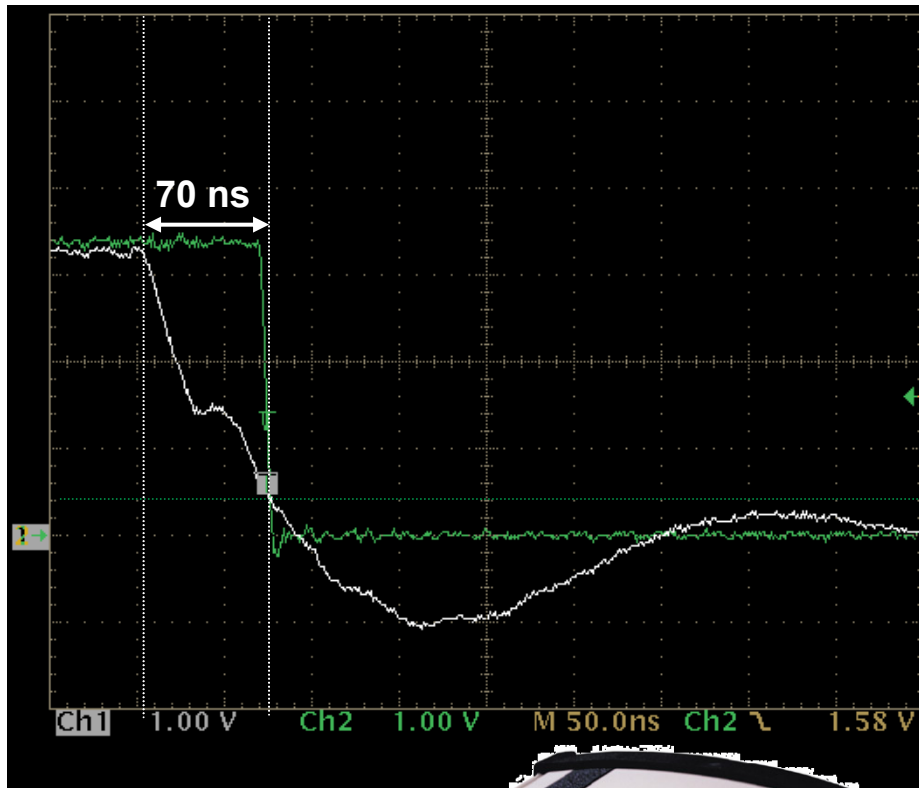
TMS timing



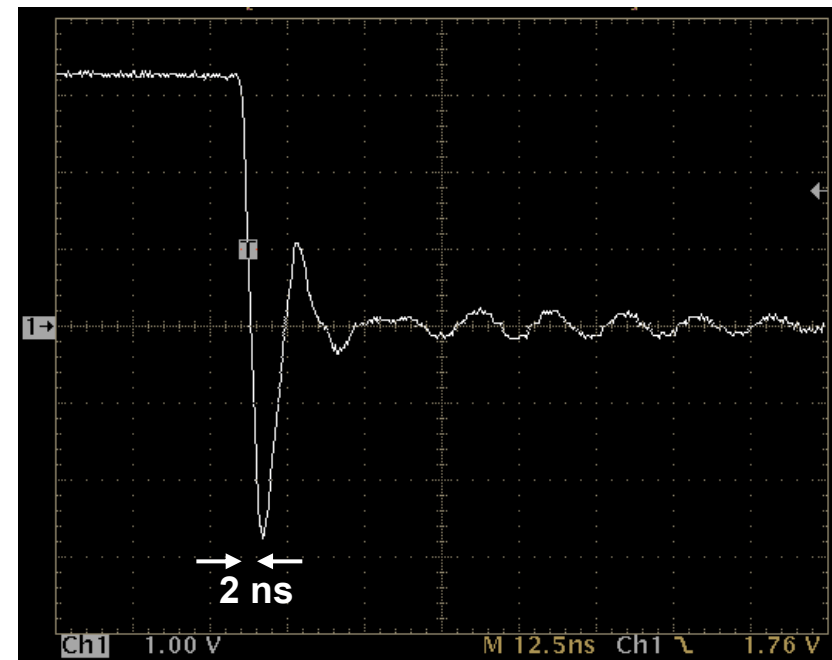
Validation of TMS timing

- NovAtel OEM4-G2 L1/L2 GPS receiver
- Temex SR100 GPS disciplined Rb clock
- TMS “timetag” repeatability and linearity
- All delays through TMS system
- TMS simulator output
- H-field simulator injection

NovAtel 1PPS output...

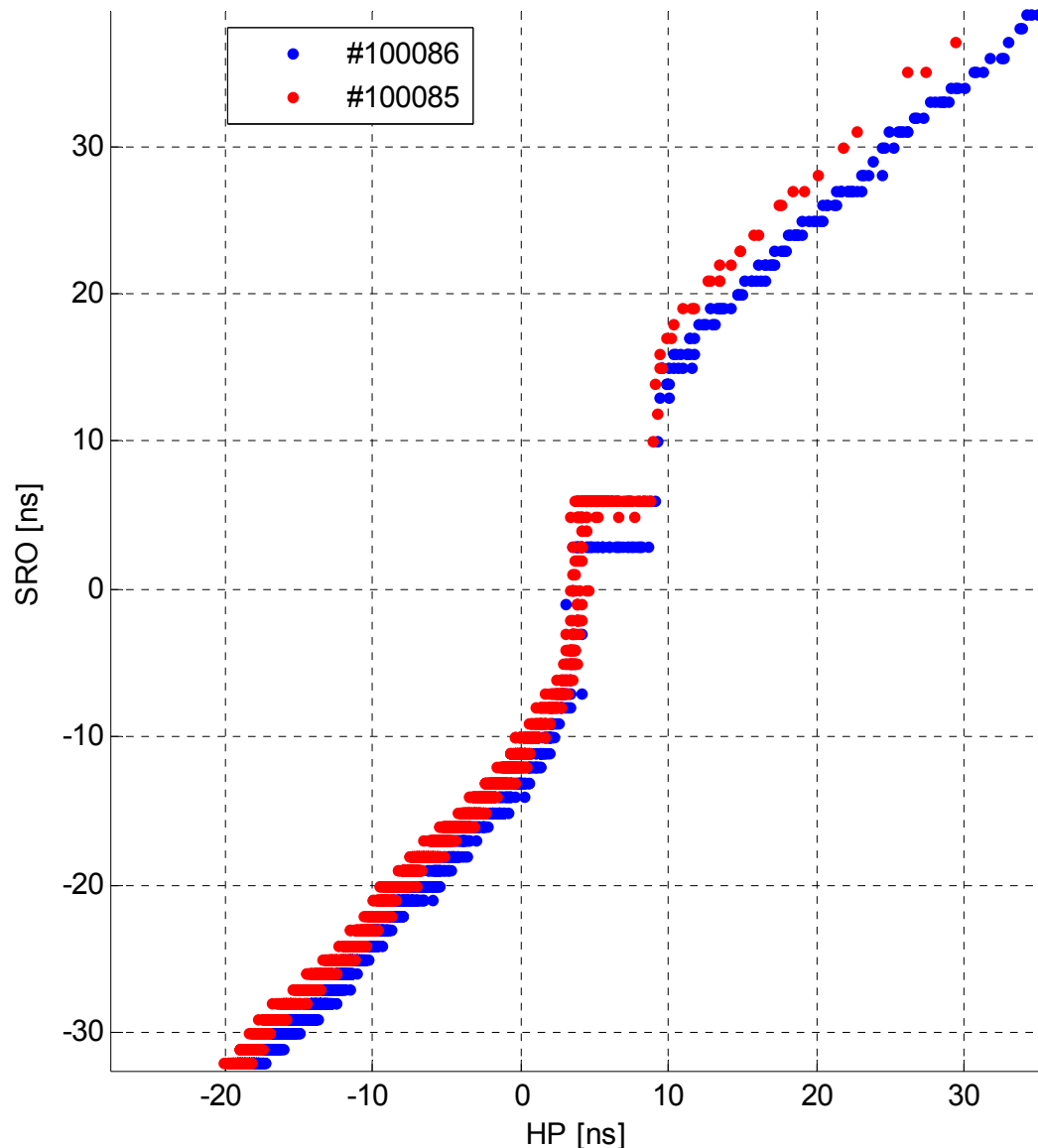


OEM4-G2 ProPak

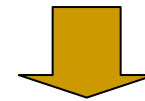


OEM4-G2 PowerPak

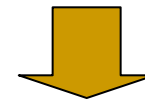
Temex SRO100 phase comparator...



Temex SRO uses phase comparator to measure relation between 1PPS in and 1PPS out of the Rb clock



Measurement unreliable

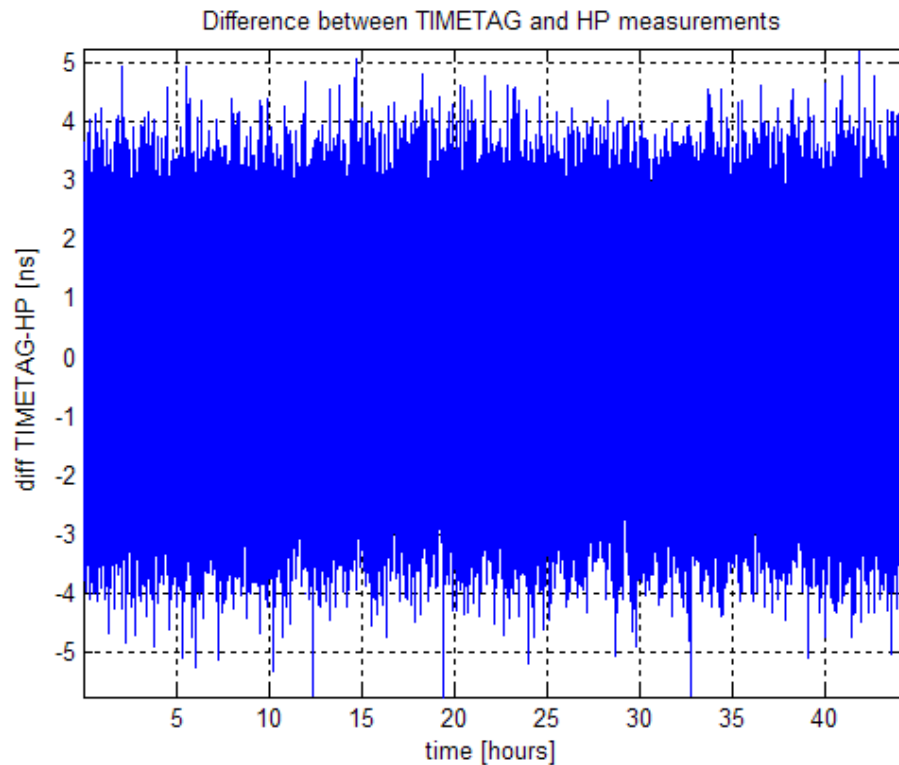


Solution: TMS measures relation using second "timetag" input

TMS timetag repeatability and linearity

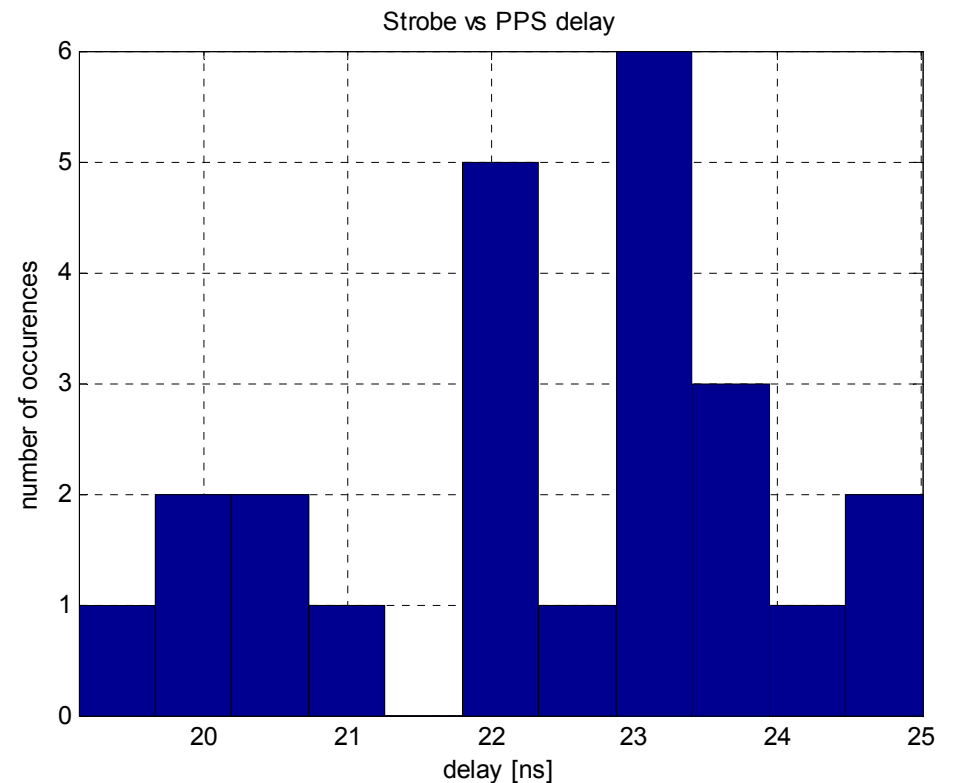
Linearity test:

44 hour sweep through 121 μ s

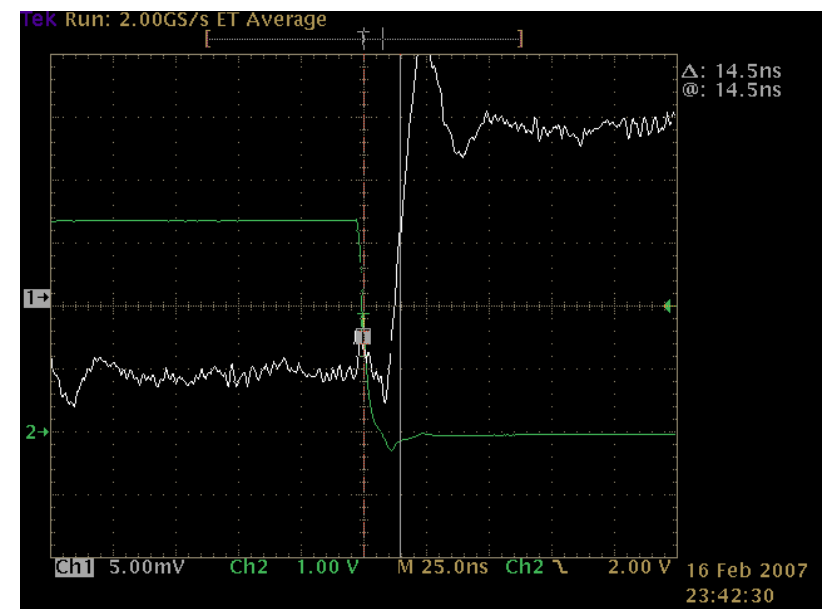
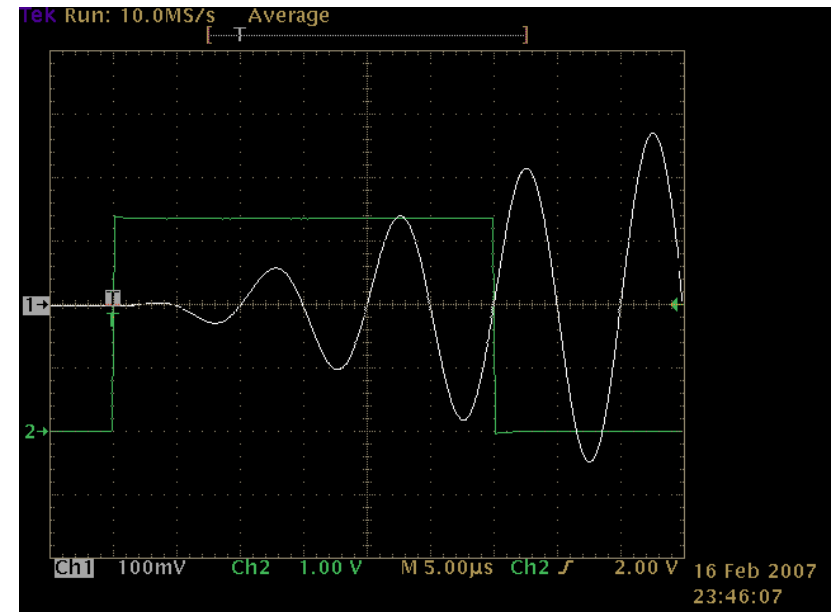
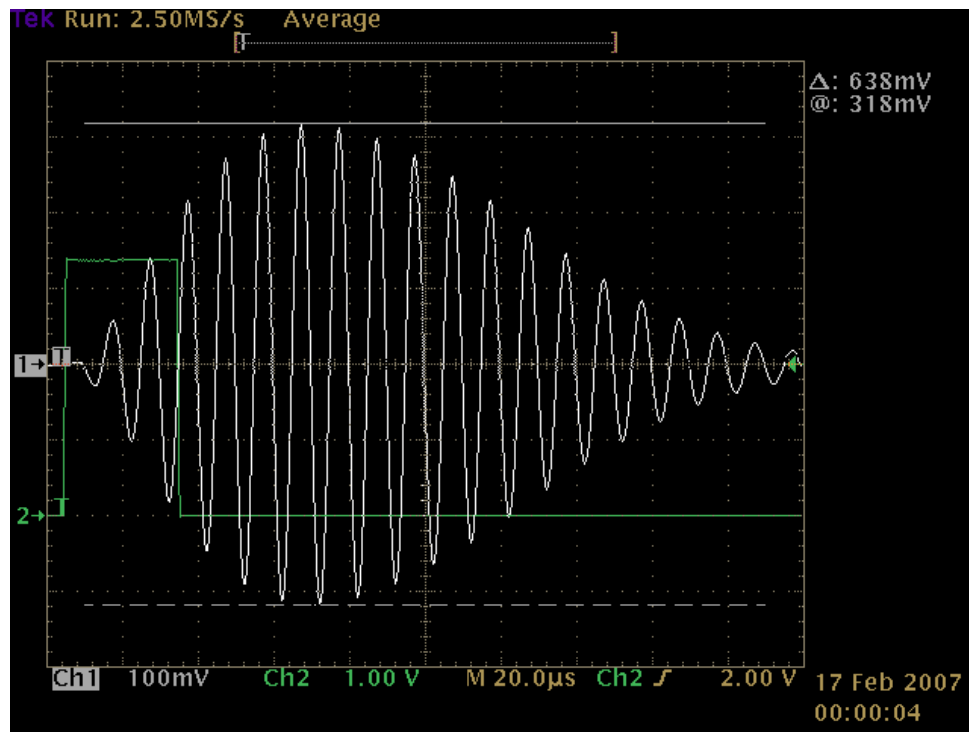


Repeatability test:

25 cold starts

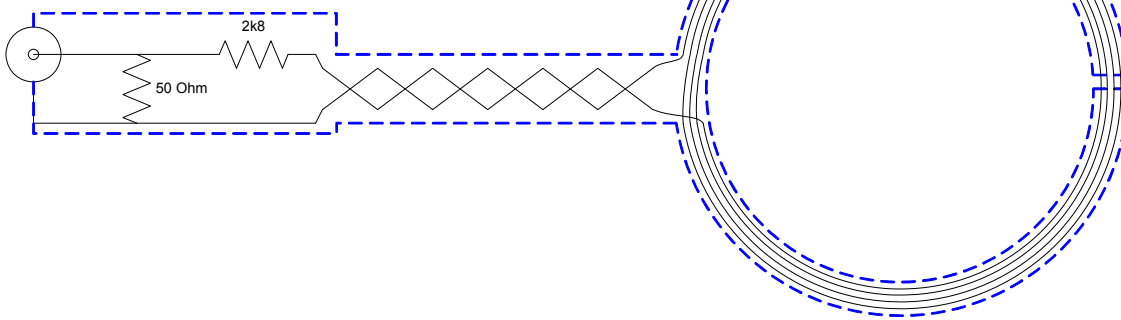


TMS Simulator output

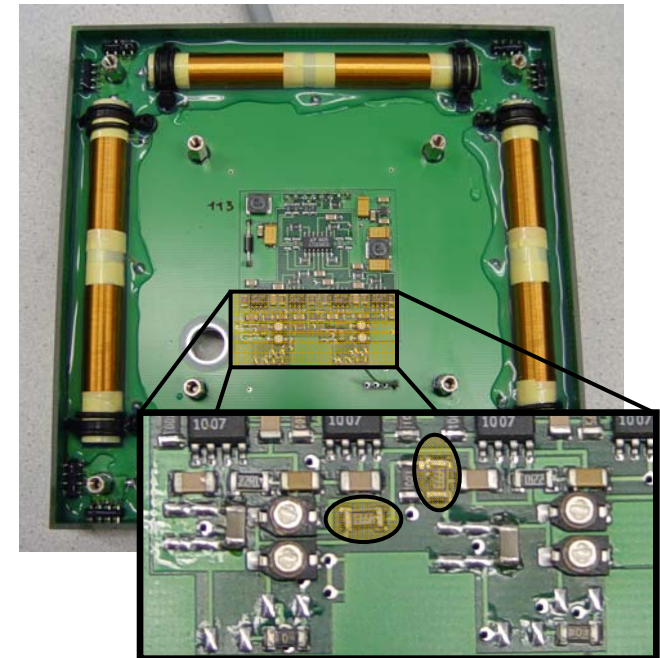
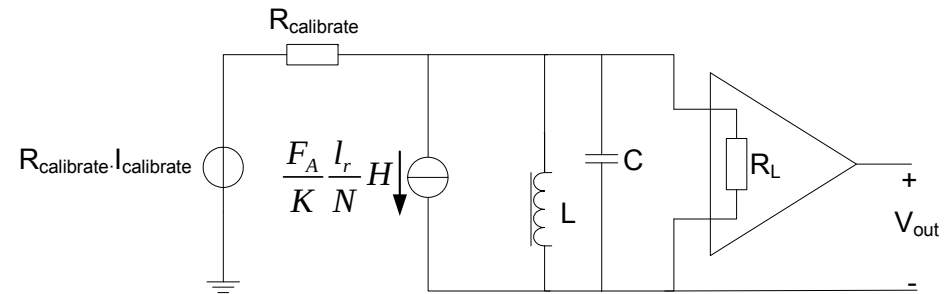


Simulator signal injection

Loop injection

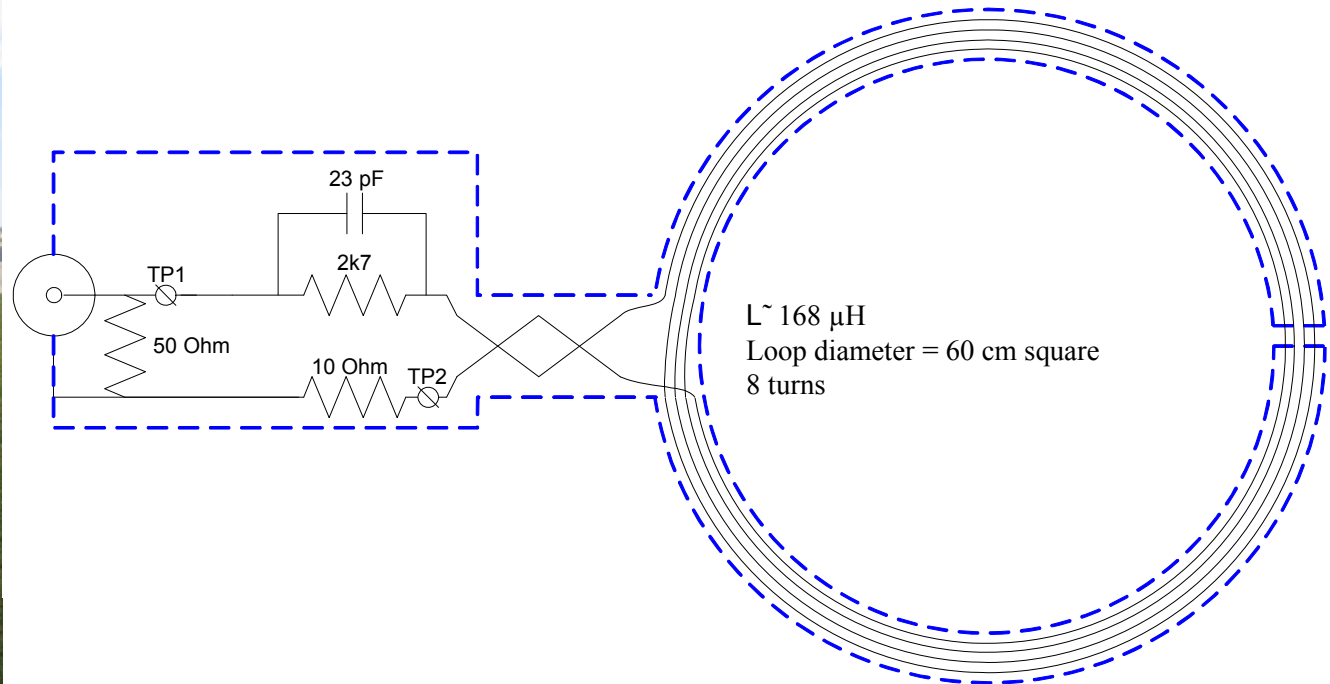


Resistor injection



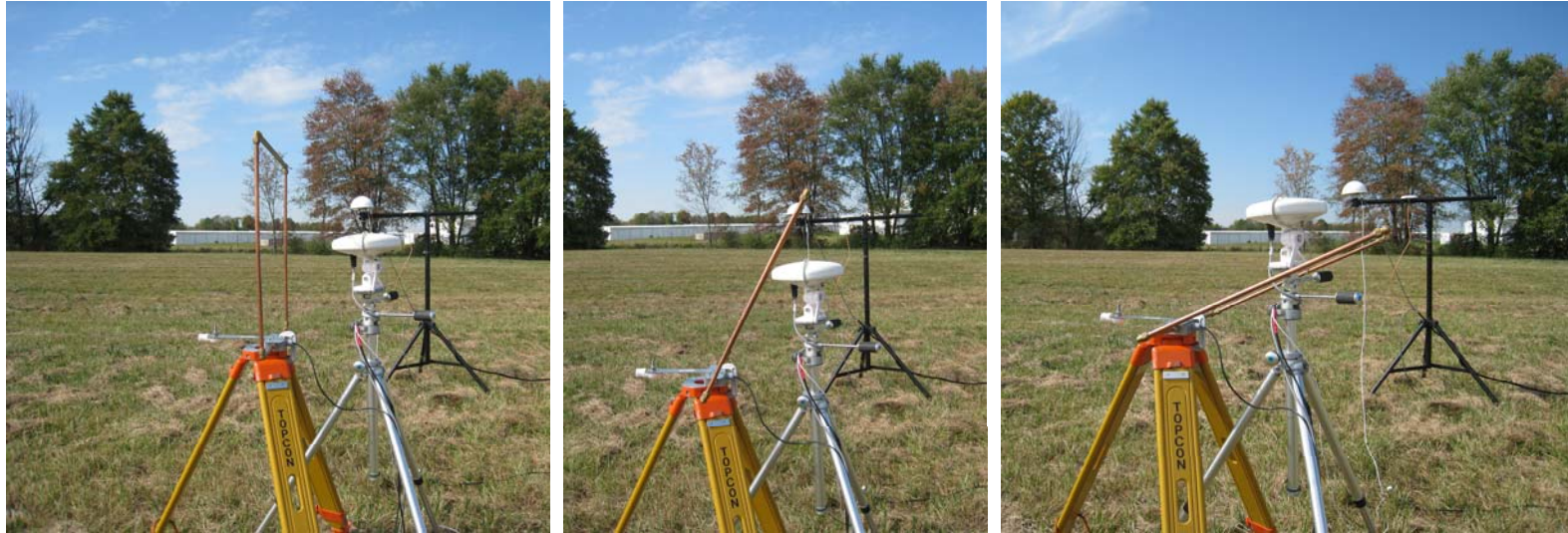
Delay of injection circuitry??

Calibration of simulator signal injection delay



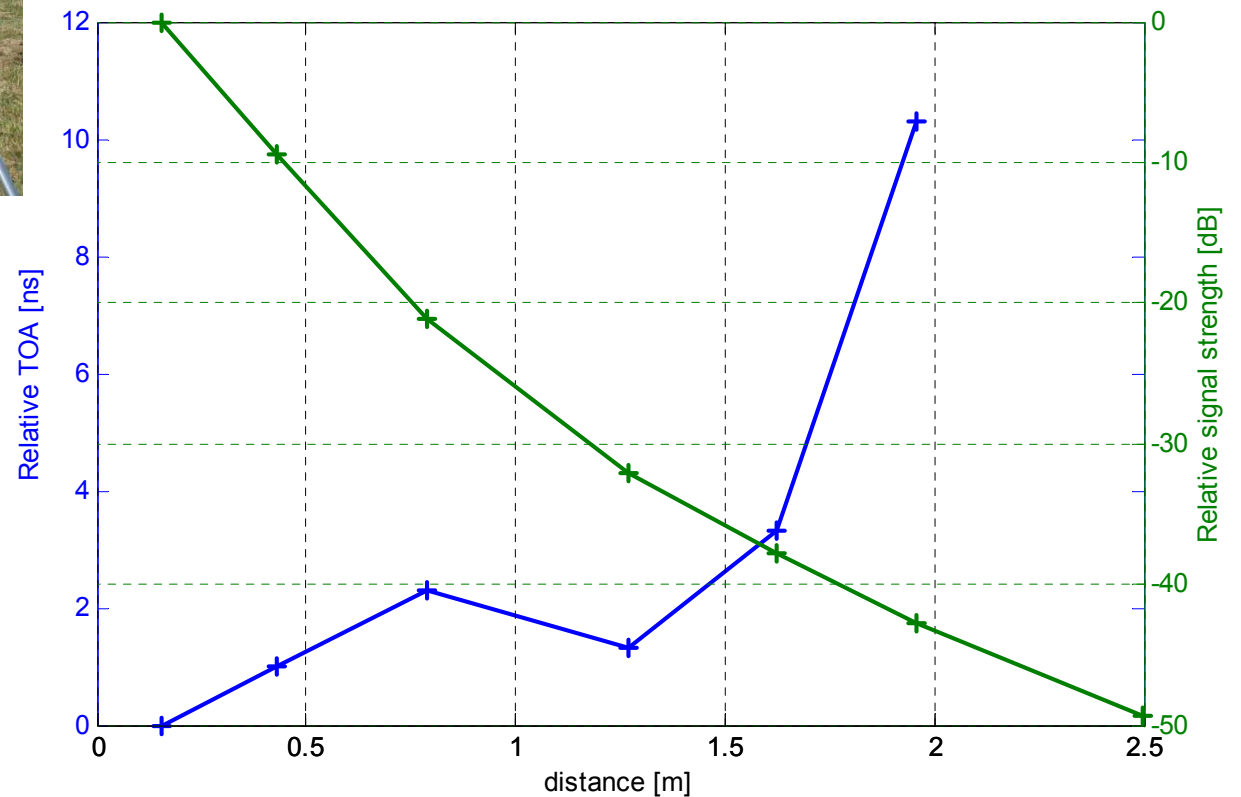
- “Tuning” capacitance compensates for inductance of injection loop
- TP2-TP1 gives total “loop delay.” Effective delay half-way?

Validation of calibration loop: Influence vertical orientation of calibration loop



	Sim TOA	δ TOA	Signal Strength	δ Signal Strength	Beam orientation
Vertical (0°)	114,201.1	0.0 ns	79.9 dB	0 dB	40.0°
≈30 degrees	114,200.9	-0.2 ns	84.7 dB	+4.8 dB	40.7°
≈45 degrees	114,199.5	-1.6 ns	83.8 dB	+3.9 dB	44.0°
≈60 degrees	114,200.9	-0.2 ns	68.8 dB	-11.1 dB	86.7°
Horizontal (90°)	114,186.0	-15.1 ns	53.2 dB	-26.7 dB	166.3°
Vertical (0°)	114,202.7	1.6 ns	79.3 dB	-0.6 dB	42.1°

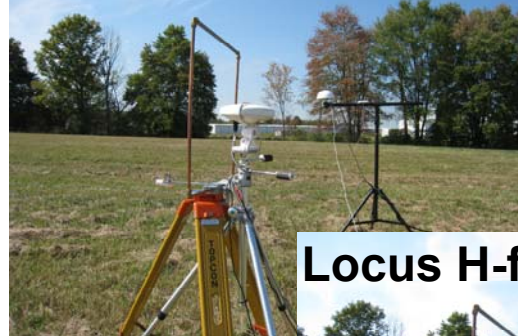
Validation of calibration loop: Influence of distance to calibration loop



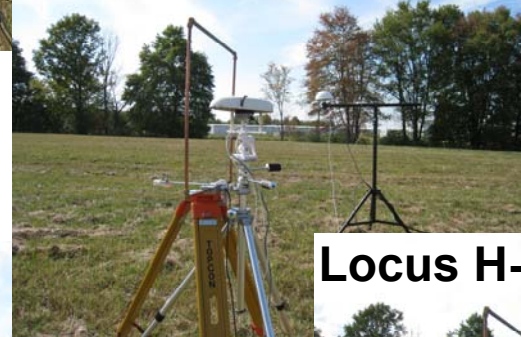
“Factory” calibration of heading-dependent errors and simulator injection delay



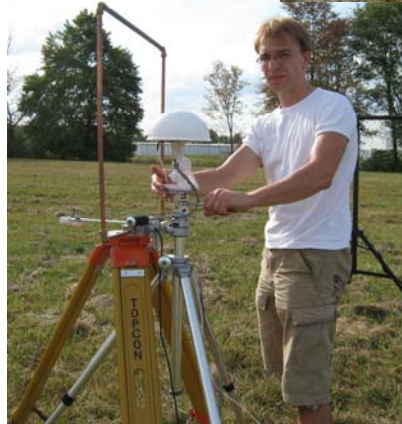
Reelektronika H-field



Locus H-field Aviation



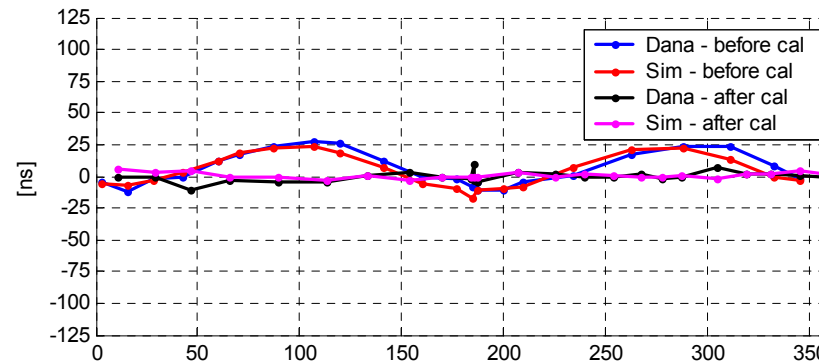
Locus H-field Maritime



Results factory calibration H-field antennas



Reelektronika H-field

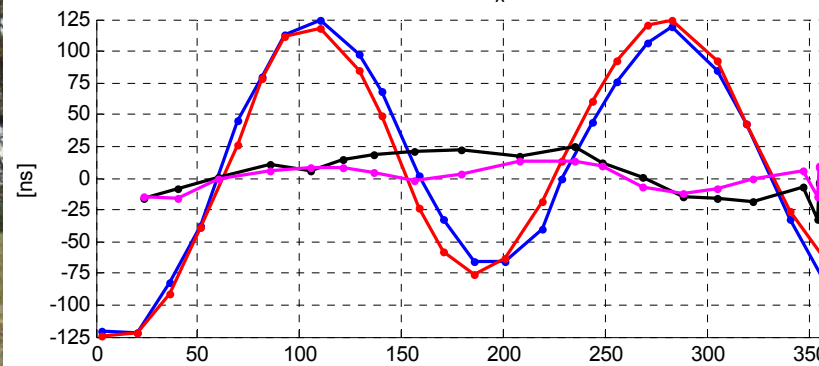


Sim-inject delay
L: -12 ns, R: -134 ns

heading-dependent:
Before cal: 37 ns pp
After cal: 9 ns pp



Locus H-field Aviation

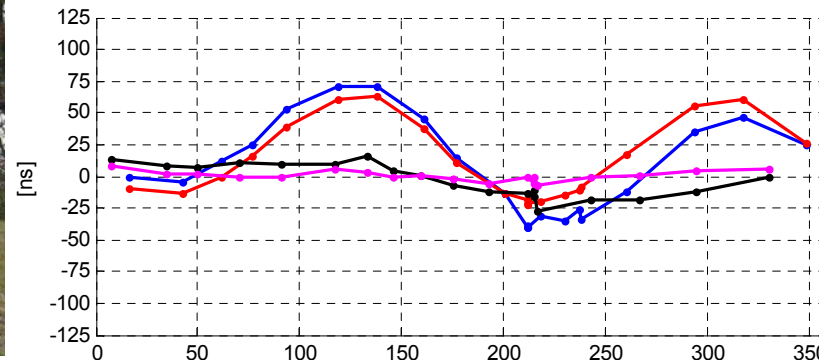


Sim-inject delay
L: -9 ns

heading-dependent:
Before cal: 220 ns pp
After cal: 40 ns pp

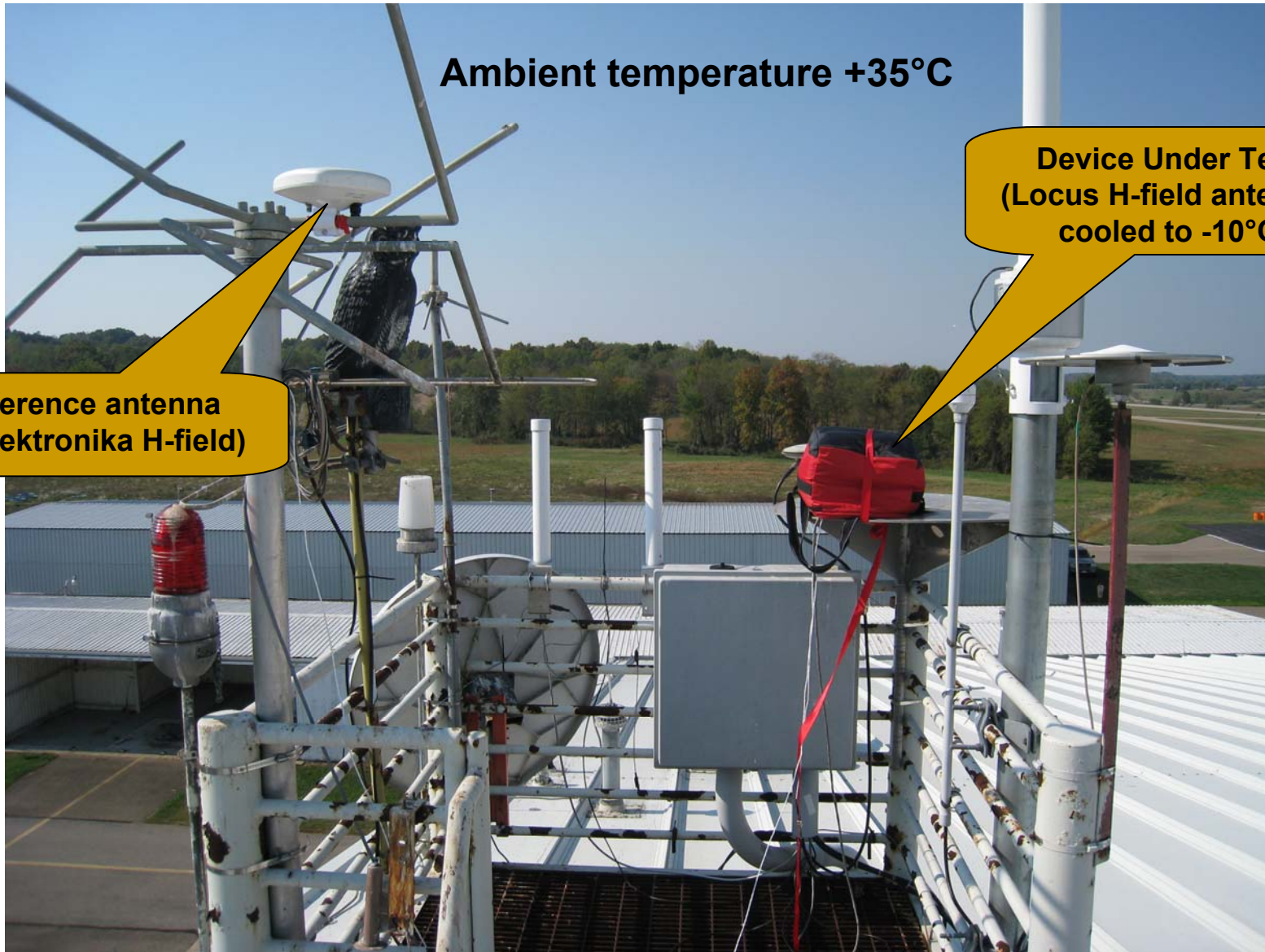


Locus H-field Maritime

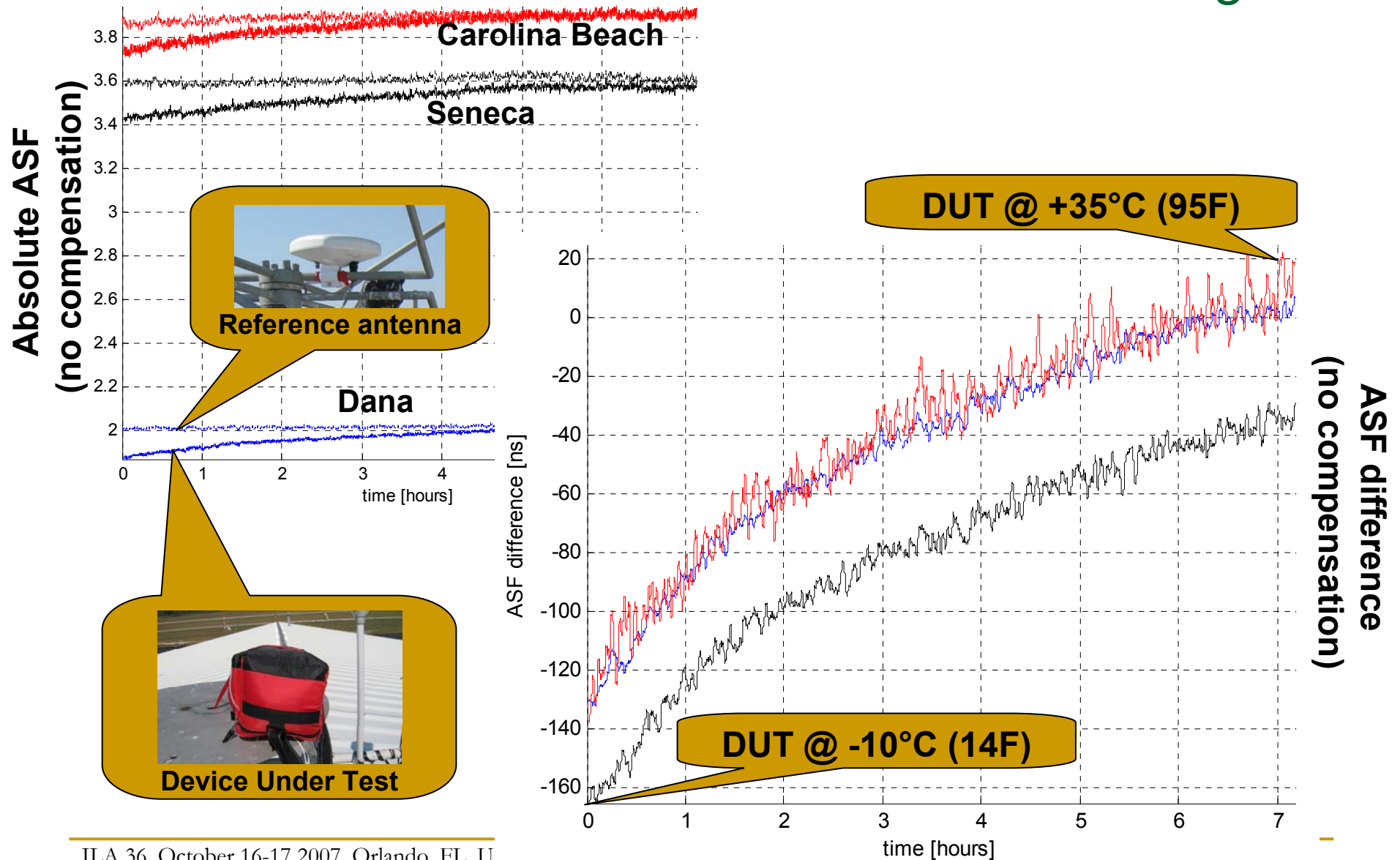


heading-dependent:
Before cal: 110 ns pp
After cal: 35 ns pp

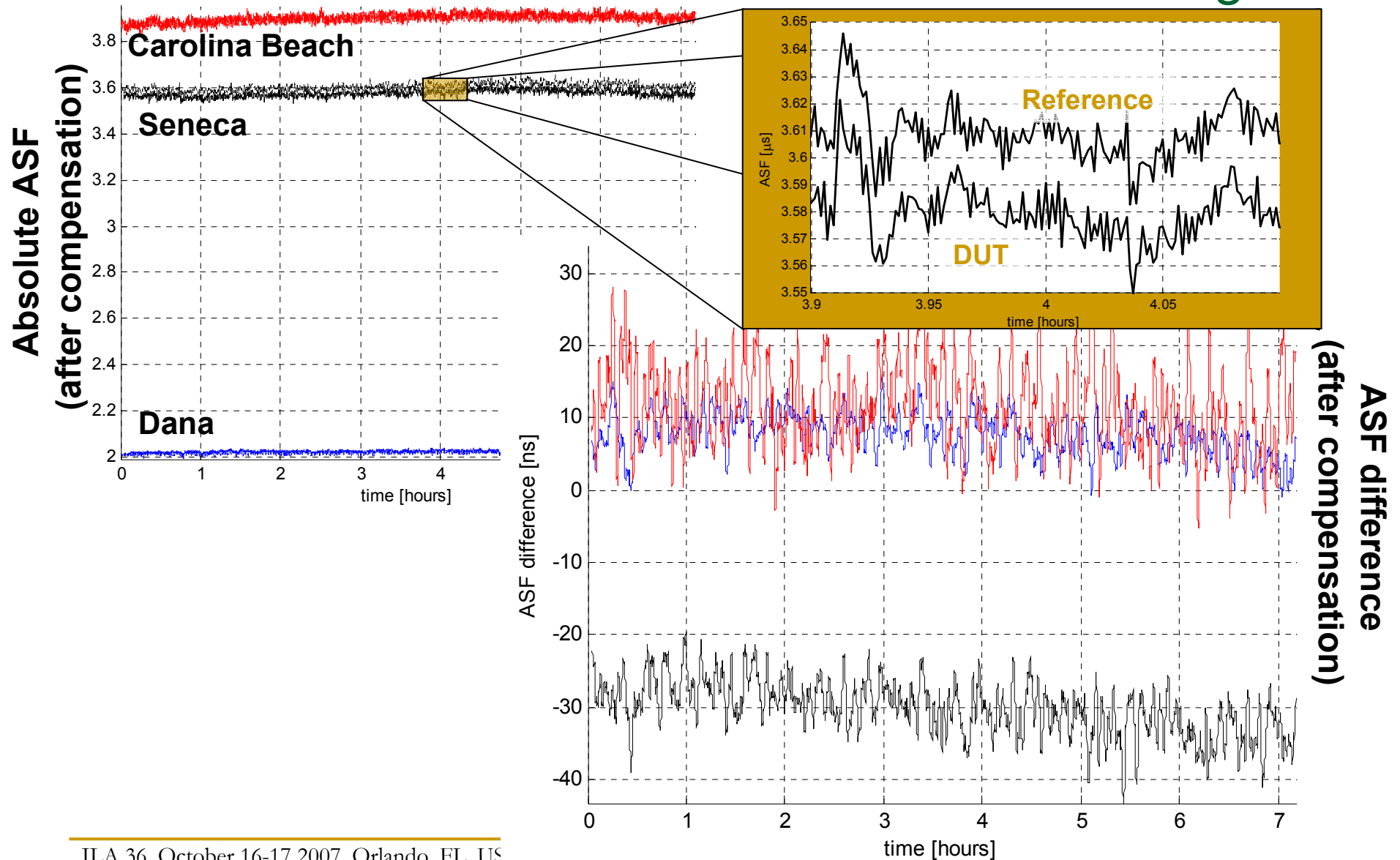
Temperature effects Locus H-field antenna



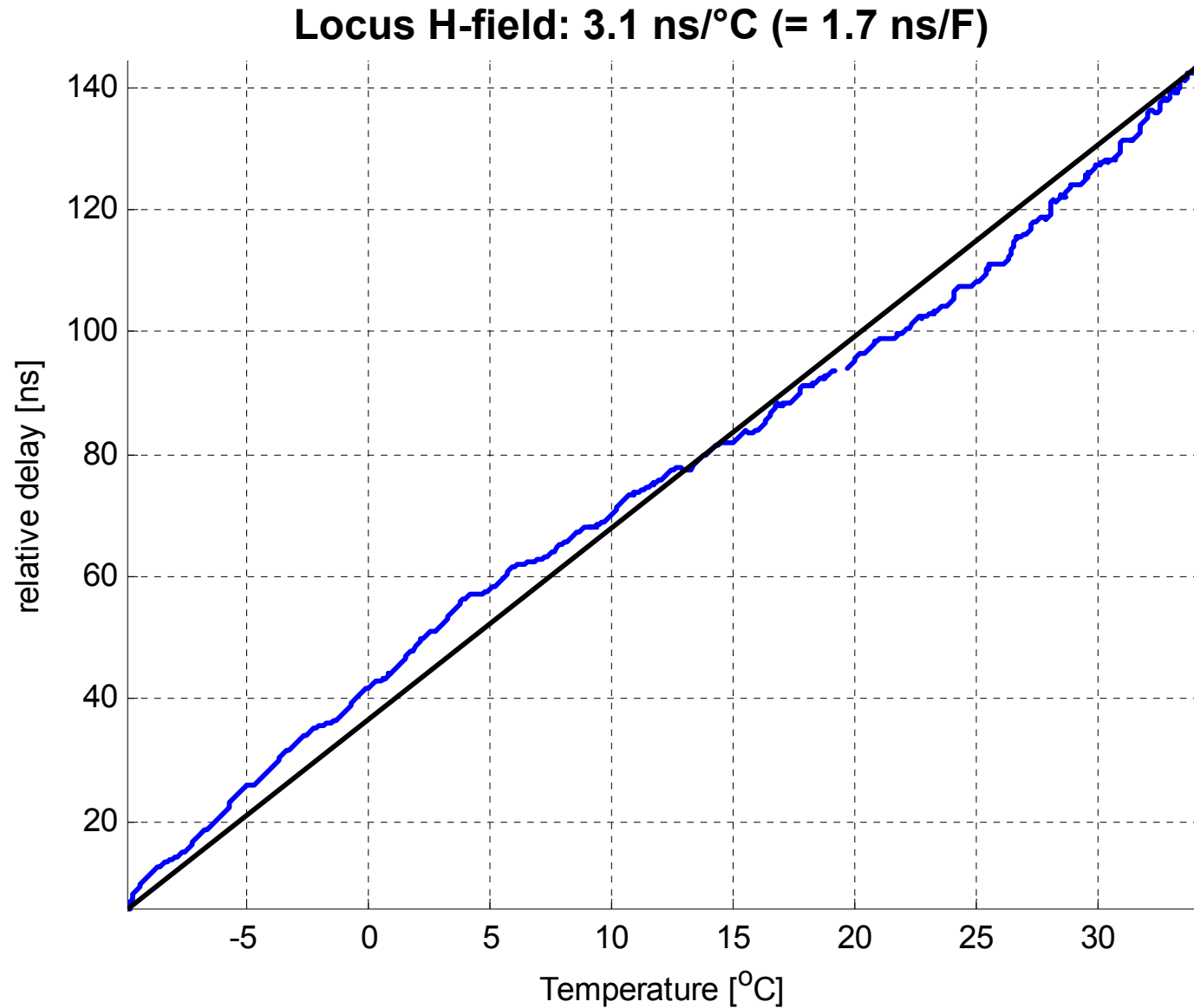
Temperature effects Locus H-field antenna *not calibrated* with simulator signal



Temperature effects Locus H-field antenna *after calibration* with simulator signal



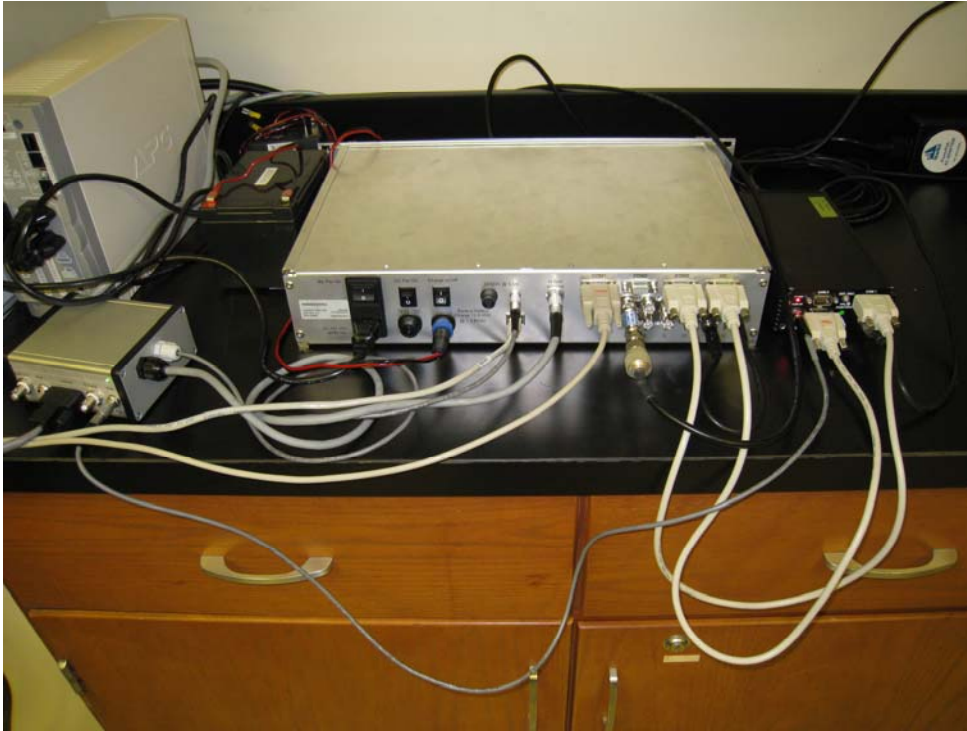
Temperature effects H-field Locus antenna



Estimate TMS timing error budget

All units in [ns]	Not calibrated / compensated			Calibrated / compensated		
	Min	Typical	Max	Min	Typical	Max
GPS timing		20 ?			20 ?	
TMS delays		5			5	
TMS TimeTag	0	2.5	5	0	2.5	5
Sim Injection		10			10	
Antenna heading-dependent errors	15	50	100	5	10	20
Antenna temp-dependent errors	30	50	100	2	5	10
Total (TOA measurement noise excluded)		75			26	

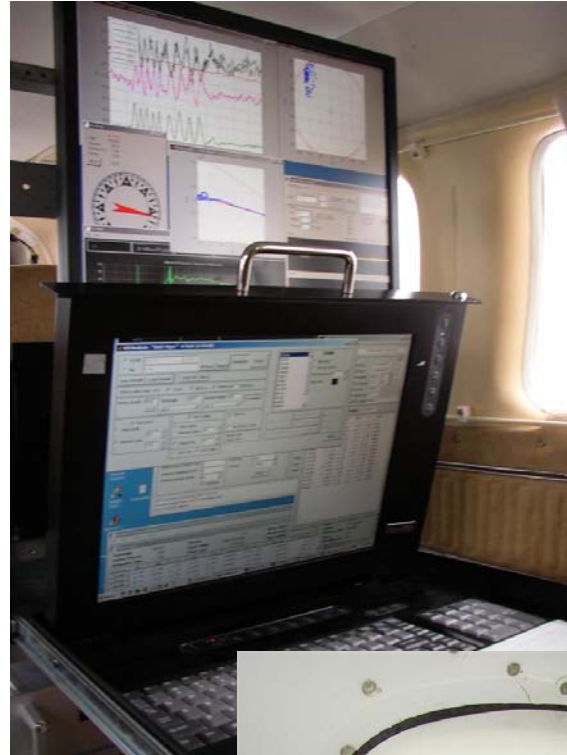
TMS long term stability testing



**Setup continuously running at
Ohio University Airport**



Data collection setup



Equipment shakedown flights



Piper Saratoga

- Flights around Ohio University
- October 2006: TMS prototype (see paper previous ILA)
- February 2007: TMS 2.0 + data collection setup

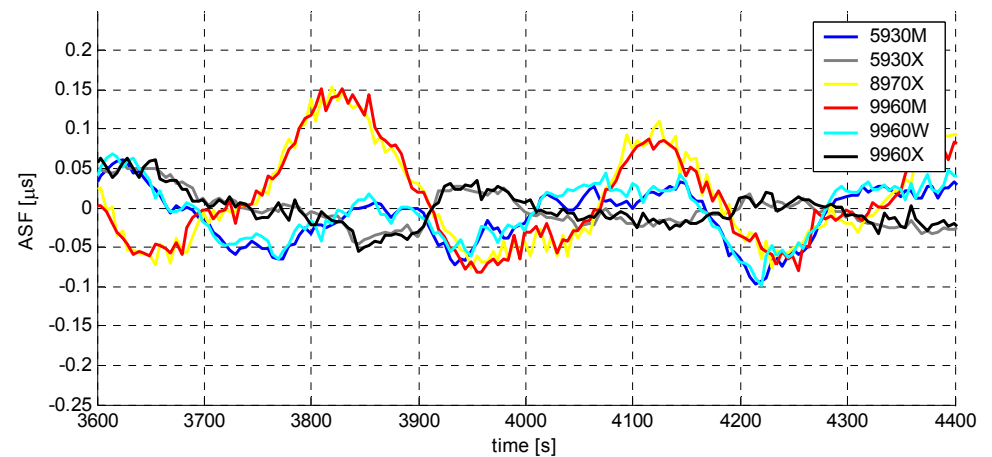
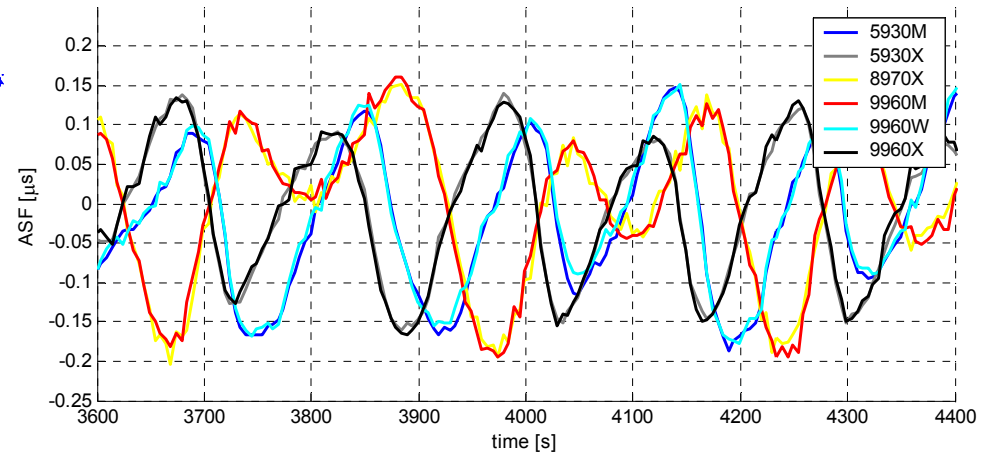
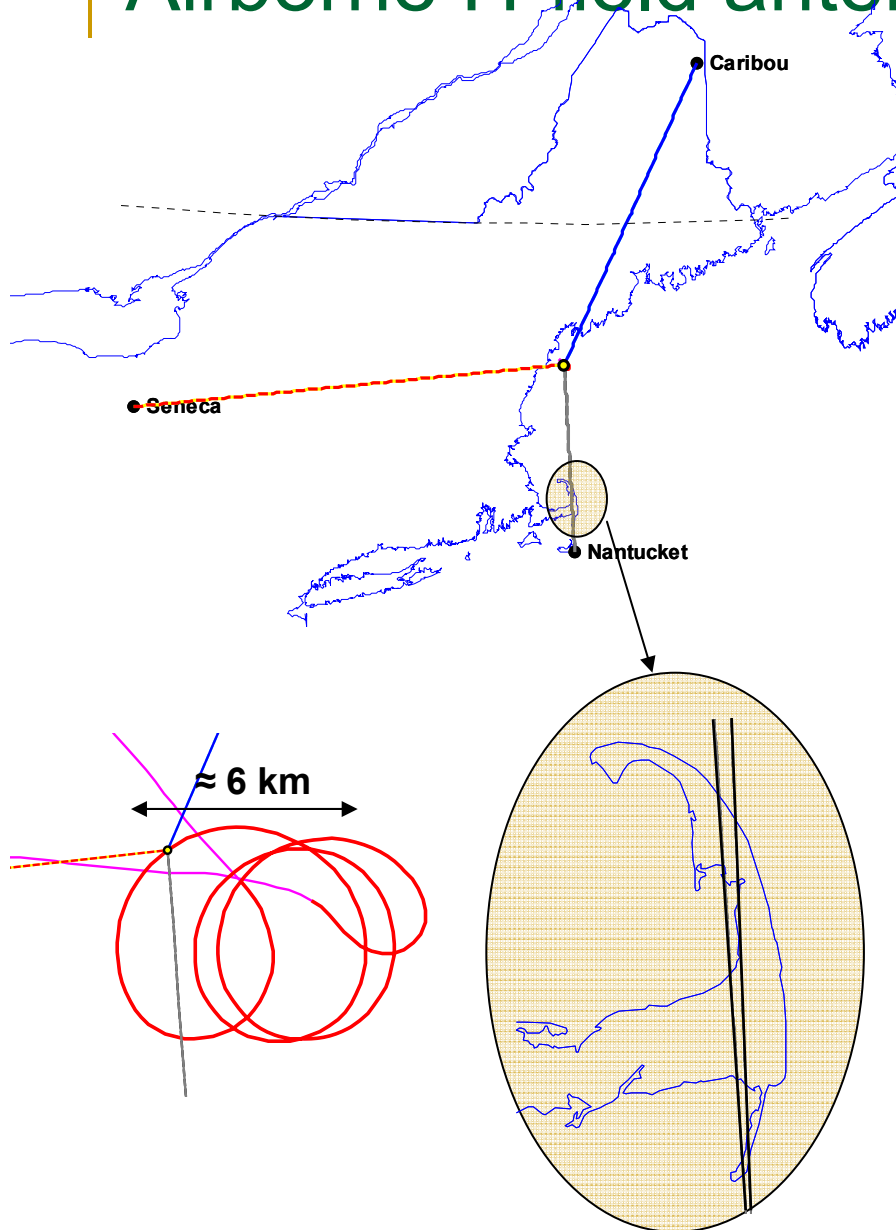


King Air C90

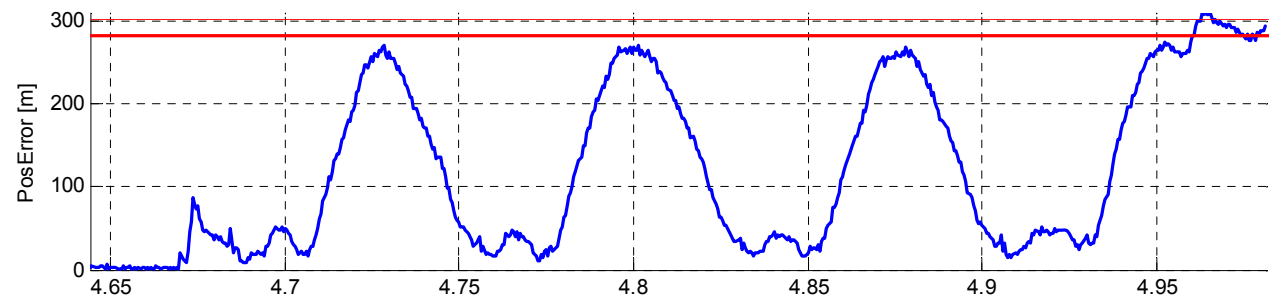
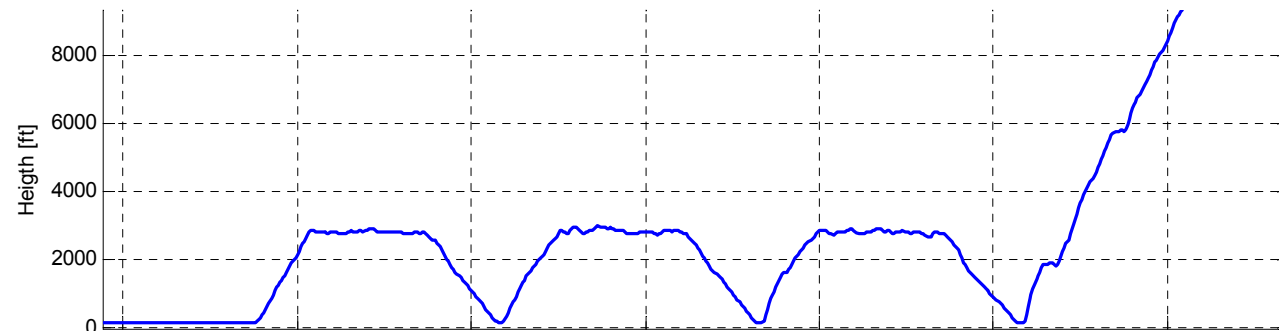
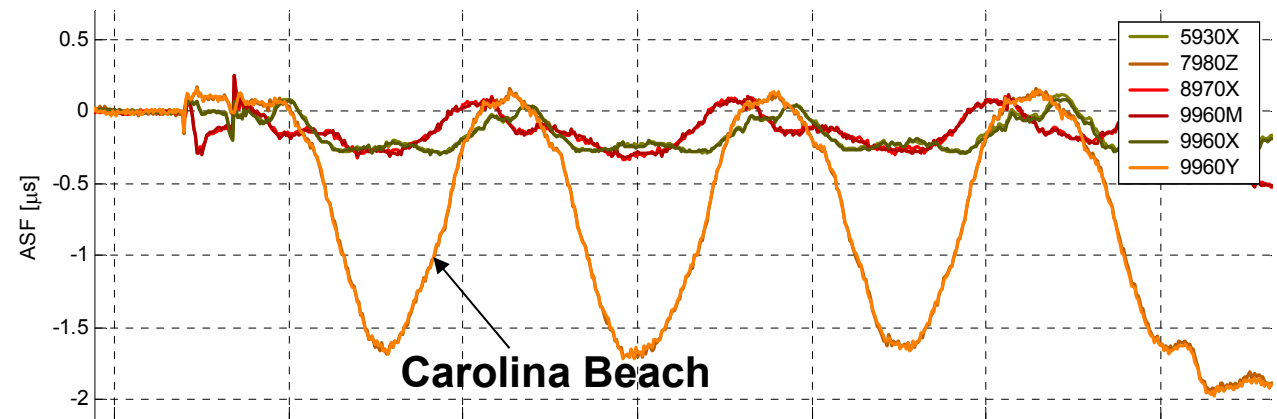
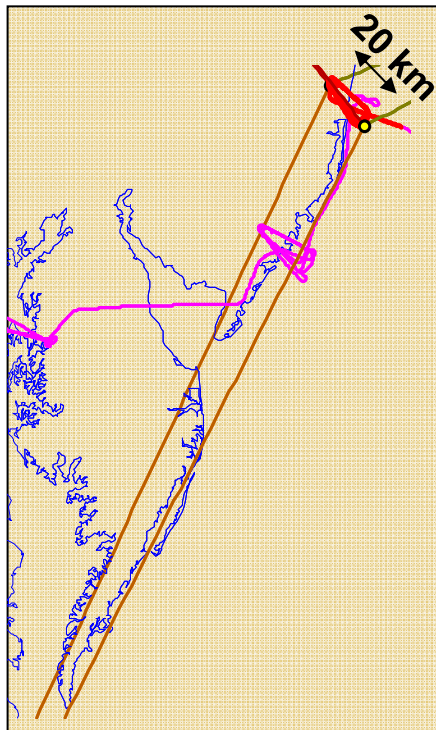
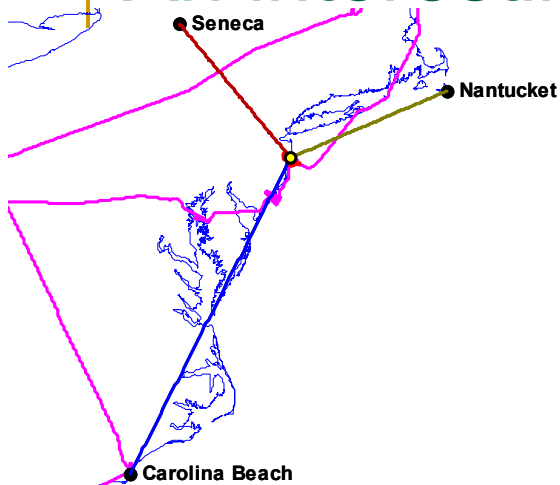
- April & September 2007
- > 20 h flight time
- ≈ 7000 km



Airborne H-field antenna calibration



An interesting airport...

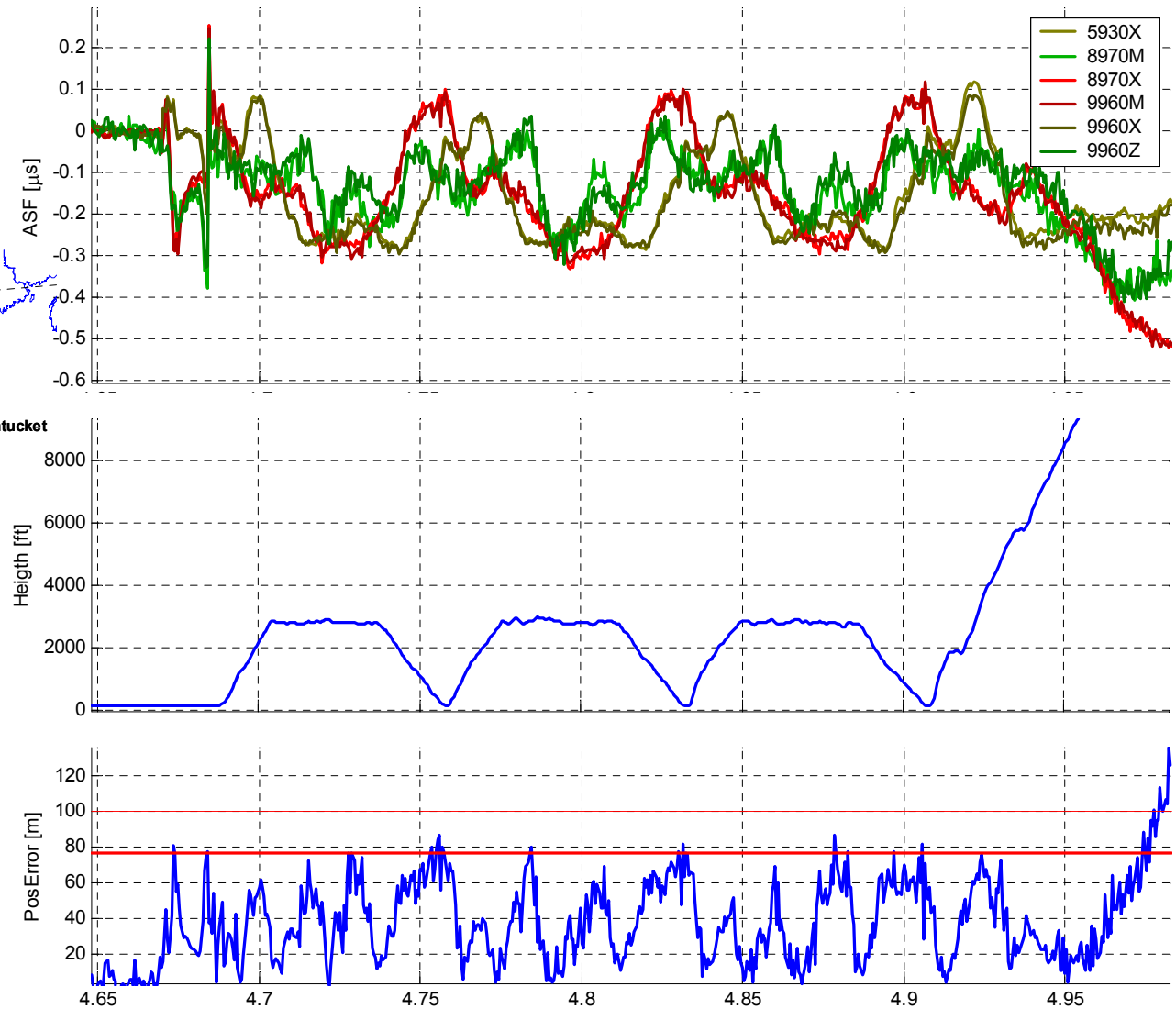
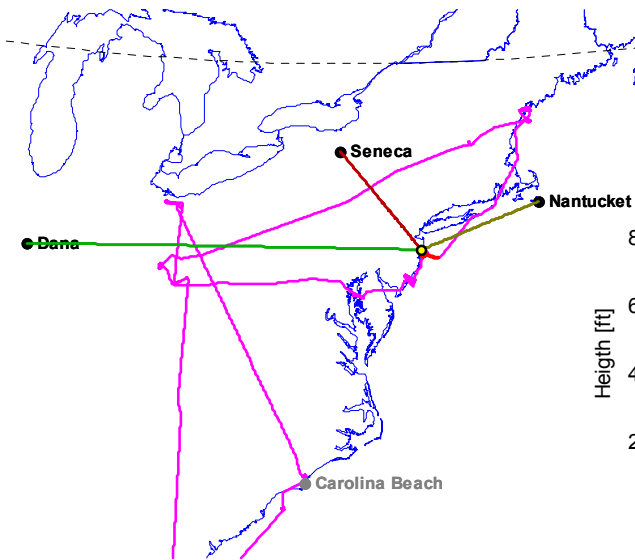


An interesting airport...

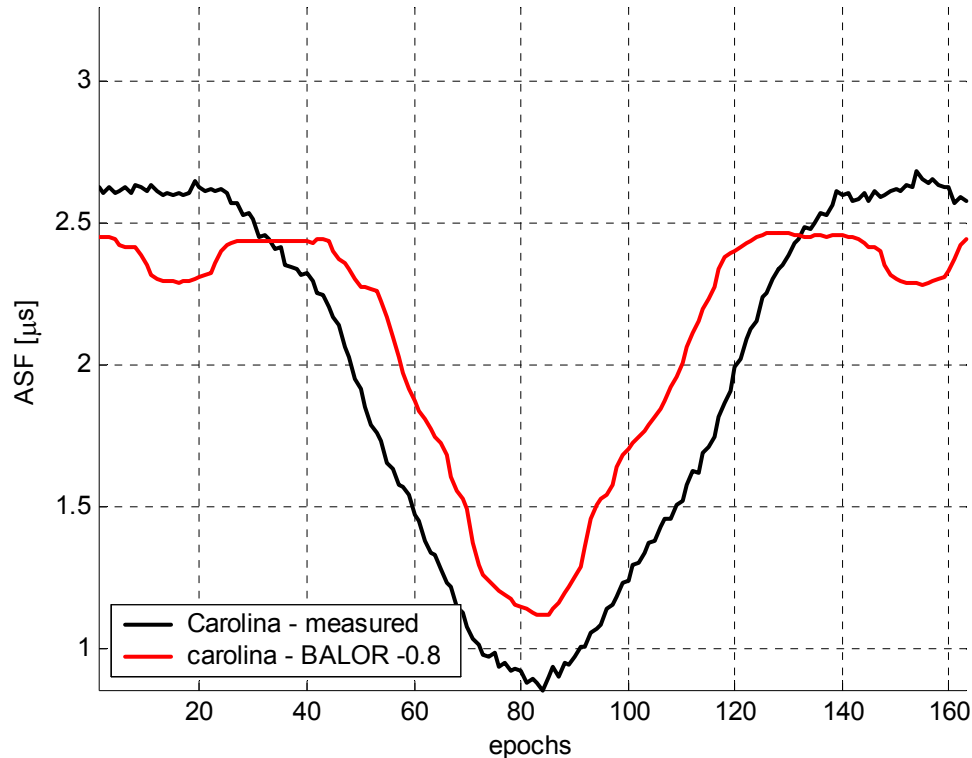
Use Dana instead of
Carolina Beach:

→ Geometry --

→ Pos performance ++



An interesting airport... what about BALOR?



Measurements ?

- SAM → TOT, ED?
- Simulator injection not yet calibrated

BALOR ?

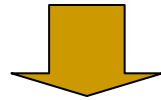
- Effective earth radius
- Conductivity
- More accurate coastline database
- ?

The current BALOR does predict that we have a problem at this airport!

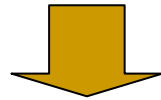
Conclusion

The Reelektronika TMS:

- High performance Loran tracking
- Absolute timing
- Versatile, Robust, Plug & Play
 - *Demonstrated and validated* -



+ calibration of H-field antennas



Let's use it!

- BALOR validation campaigns
- HEA
- Absolute timing
- ...

Acknowledgements

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The authors would like to thank the Program Office manager, Mr. Mitchell J. Narins, for his assistance in making this research possible.