Loran C Additional Secondary Factors: Implications for Meeting Required Navigation Performance (RNP) 0.3—An Update
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ILA-34 Conference and Technical Symposium
Santa Barbara, California
October 19, 2005
Overview

• Use of locally measured and/or calculated ASF values is key for Loran C to meet accuracy requirements of RNP (0.3)
• Ohio University has been collecting Loran C data at six east coast/mid west airports over the past two years
• Flights are conducted in early spring and late summer seeking to establish patterns for ASF values
• Goal is to verify if a single set of ASF values can serve an entire airport covering all runway approaches
Outline

• Loran-C Signal Propagation
• ASF Measurement System
• ASF* Derivation
• Required Navigation Performance
• Flight Test Results
• Summary and Conclusion
Loran C Signal Propagation

• “Primary” factor (PF) is signal delay through the atmosphere as compared to a vacuum
• “Secondary” factor (SF) is signal delay over seawater
• “Additional” secondary factor (ASF) accounts for additional delays over terrain due to ground conductivity (moisture/temperature dependent)
• ASFs contribute largest positional errors for Loran and their incorporation is essential for local accuracy
ASF Measurement System

• 2 SatMates (E and H-field)
• 12 channel GPS/WAAS
• Notebook PC with ASF software utility for rapid on-site ASF calculation
• Flashcard for easy data storage and transfer to the aircraft receiver
• UPS/ruggedized unit for field use
ASF* Derivation

• Collect ~ 1 hour Loran and GPS data at airport site
• ASF software utility generates local ASF* values
  • TOAs are measured using Loran C receiver clock locked to a composite frequency derived from all stations being tracked
  • Measured TOAs are differenced from TOAs calculated using GPS-derived position and the PF and SF yielding AFS*
  • ASF* contains UTC offset, receiver delays
  • Common receivers (ground/air) are used to account for the receiver delays
  • Loran C system is well managed and UTC offsets within the system remain reasonably constant over time
• Second utility reads ASF* values and burns flashcard
• Flashcard is used to initialize aircraft Loran C receiver
ASF System in Operation

- ASF Measurement System
- Tripod holds GPS, E-field and H-field Loran antennas
- Shown here in operation at Jacksonville, Florida
  - Craig Municipal Airport
Example ASF* File for an Airport

Typical ASF* values:
#ASF 8970M -0.906us [13500]
#ASF 8970X 0.429us [13498]
#ASF 8970Y 0.685us [13500]
#ASF 9960M 0.39us [13500]
#ASF 9960W 27.5us [8]
#ASF 9960Z -0.83us [13500]
#ASF 9960X 2.18us [13314]
#ASF 8970W 2.88us [13486]
#ASF 7980M -0.589us [13456]
#ASF 7980W -1.4us [13470]
#ASF 8970Z 0.118us [13468]
#ASF 7980Z -0.271us [13444]
#ASF 8290M 0.324us [13450]
#ASF 8290W 0.665us [13456]
#ASF 8290X 0.24us [13364]
#ASF 9610X 0.495us [12358]
#ASF 9610Y 0.523us [11932]
#ASF 9960Y 2.56us [13220]
#ASF 9610M -1.49us [13064]
#ASF 9610V -0.846us [13064]
#ASF 9610Z 0.261us [13064]
#ASF 7980X -0.544us [11690]
#ASF 7980Y 0.799us [6610]
Required Navigation Performance (RNP) 0.3
(From RTCA DO-236B)
Flight Tests From March 2004

Ongoing flight tests performed by Ohio University’s Avionics Engineering Center (AEC) using King Air, C-90SE twin turboprop
Flight Test Results from Four Locations

- Norwalk-Huron County Airport (5A1) Ohio
- Atlantic City International Airport (ACY)
- Portland International Jetport (PWM)
- Craig Municipal/Jacksonville Airport (CRG)
## ASF* Values for 5A1

### NORWALK-HURON COUNTY AIRPORT (5A1) OHIO (values in microseconds)

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10 nmi Approach/10 nmi Departure--Runway 10/28 at 5A1--8/24/05
10 nmi Approach/10 nmi Departure--Runway 10/28 at 5A1--8/24/05

- **Along Track Error**
- **Cross Track Error**
- **Altitude/10**
## ASF* Values for ACY

### ATLANTIC CITY INTERNATIONAL AIRPORT (ACY) NEW JERSEY (values in microseconds)

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LOCUS

5 nmi Approaches to Runway 13 at ACY

Feet
Along Track Error
Cross Track Error
Altitude/10
## ASF* Values for PWM

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10 nmi Approach with Old ASFs to Runway 11 at PWM -- 8/30/05

21 nmi point
10 nmi Approach with Old ASFs to Runway 11 at PWM--8/30/05

Feet

Along Track Error
Cross Track Error
Altitude/10
10 nmi Departure on Runway 11 at PWM--8/30/05

- **Along Track Error**
- **Cross Track Error**
- **Altitude/10**

Feet
10 nmi Departure on Runway 11 at PWM--8/30/05

10 nmi point
10 nmi on Runway 11 at PWM--8/31/05

Along Track Error
Cross Track Error
Altitude/10
### ASF* Values for CRG

**Jacksonville/Craig Municipal Airport (CRG) Florida (values in microseconds)**

<table>
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5-nmi Approaches to Runway 32 at CRG--9/1/05

- Along Track Error
- Cross Track Error
- Altitude/10

Feet

- 800
- 600
- 400
- 200
- 0
- -200
- -400
- -600

Summary

- Locally generated ASF* measurements demonstrate year-to-year (temporal) consistency but trials to date are limited.
- Flight measurements demonstrate that cross-track error is well behaved for stabilized approach procedures typical of those published by FAA for non-precision approach.
- Numerous flight tests (these and others previously reported) have demonstrated RNP 0.3 performance over a wide area surrounding the point where ASF* values were generated.
  - with ASF corrections derived the same day
  - with ASF corrections several months old
Conclusions

• It appears that a single set of ASF* values per airport will be sufficient to meet RNP 0.3 accuracy requirements for all runway ends.
• Twice annual updates may be needed for some airports where all-in-view geometry is limited.
• Airports surveyed to date are representative of those east of the Rocky Mountains. The inter-mountain and west coast areas need to be studied since ASF gradients can be steep.
• With new TFE equipment in place and a move to time-of-transmission control, ASFs should prove to be more stable than at present thus yielding even greater Loran C accuracy.