


Primary, Secondary, Additional Secondary Factors for RTCM Minimum Performance Specifications (MPS)

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Technical Symposium of the International Loran Association
October 13-15, 2009
Portland, ME

Purpose of Presentation

- Present definitions and equations to be used for RTCM receiver minimum performance specifications (MPS)
  - Important to have consistent definition for application of ASF, diff. Loran worldwide
- Discuss rationale for these choices
- Highlight differences with past definitions

Primary Factor (PF)

- The primary factor is commonly defined as the propagation time of the signal through the atmosphere
- The PF specified by MPS will use the following definitions
  - Speed of light, free space (c) = 299792458 m/s
  - Speed of light, atmosphere (vpf) = 299691162 m/s
  - Index of refraction in atmosphere (η) = 1.000338
- Loran-C user handbook
  - Vpf = 161,829 nm/sec = 299707308 m/s
  - Implied η = 1.000284
- Loran-C Signal Specifications
  - c = 299792458 m/s, η = 1.000338 (Appendix A)

Traditional & Alternative Definition of PF

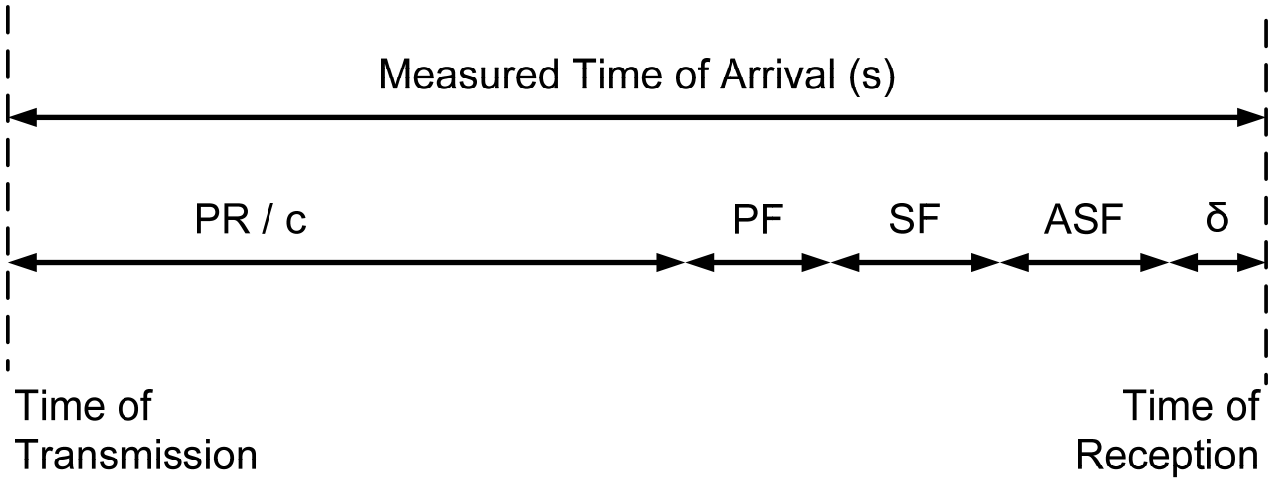
- Traditional
  - Accounts for travel time in air

$$PF(\text{sec}) = \eta \frac{d}{c}$$

- Alternative (used in Brunav equation)
  - Diff in travel time between propagation in vacuum and in air

$$PF_{alternate}(\text{sec}) = (\eta - 1)\frac{d}{c}$$

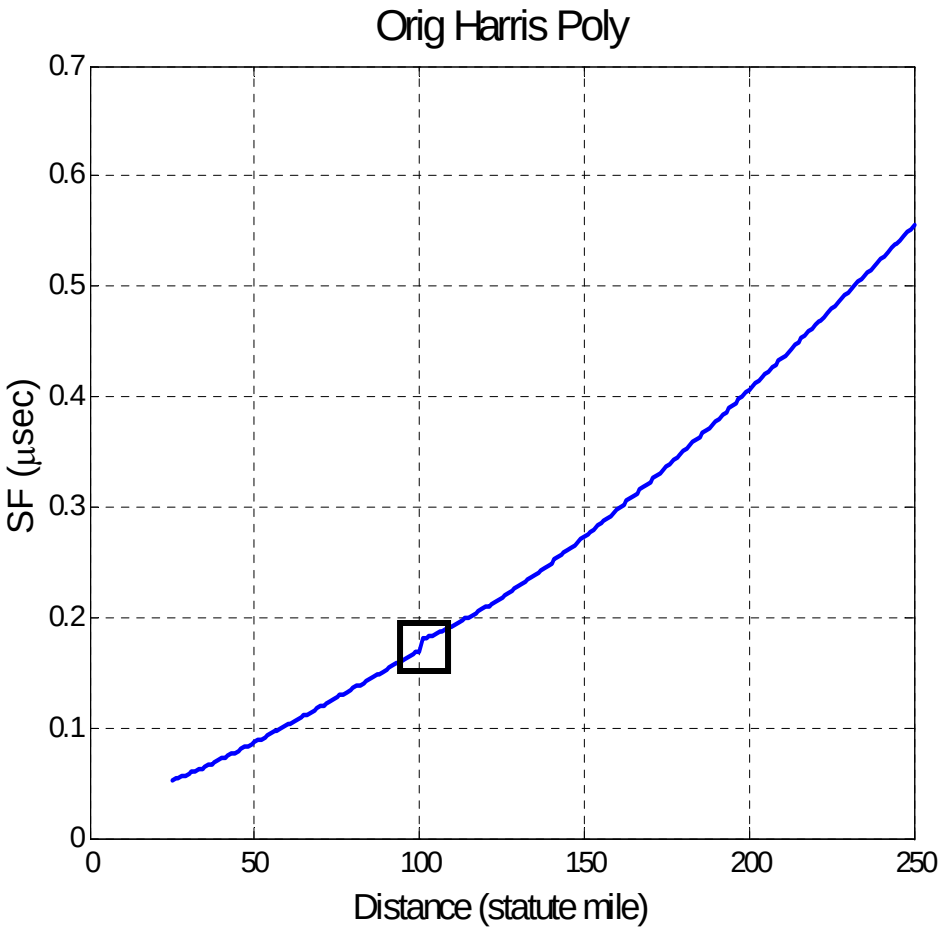
- For the MPS, it does not matter

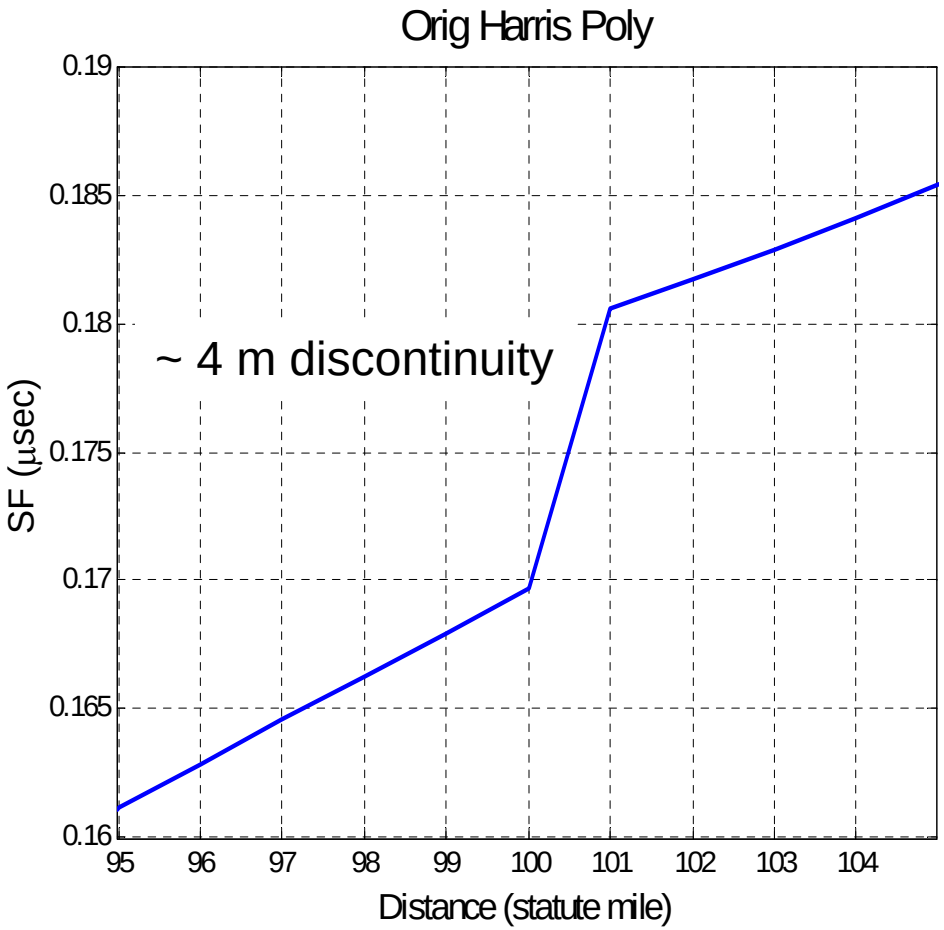


Secondary Factor (SF)

- Accounts for additional delay due to propagation over sea water.
- Harris polynomial defined in Loran User Handbook
  - It has a discontinuity
- Two possibilities
  - Brunavs
  - Modified Harris polynomial

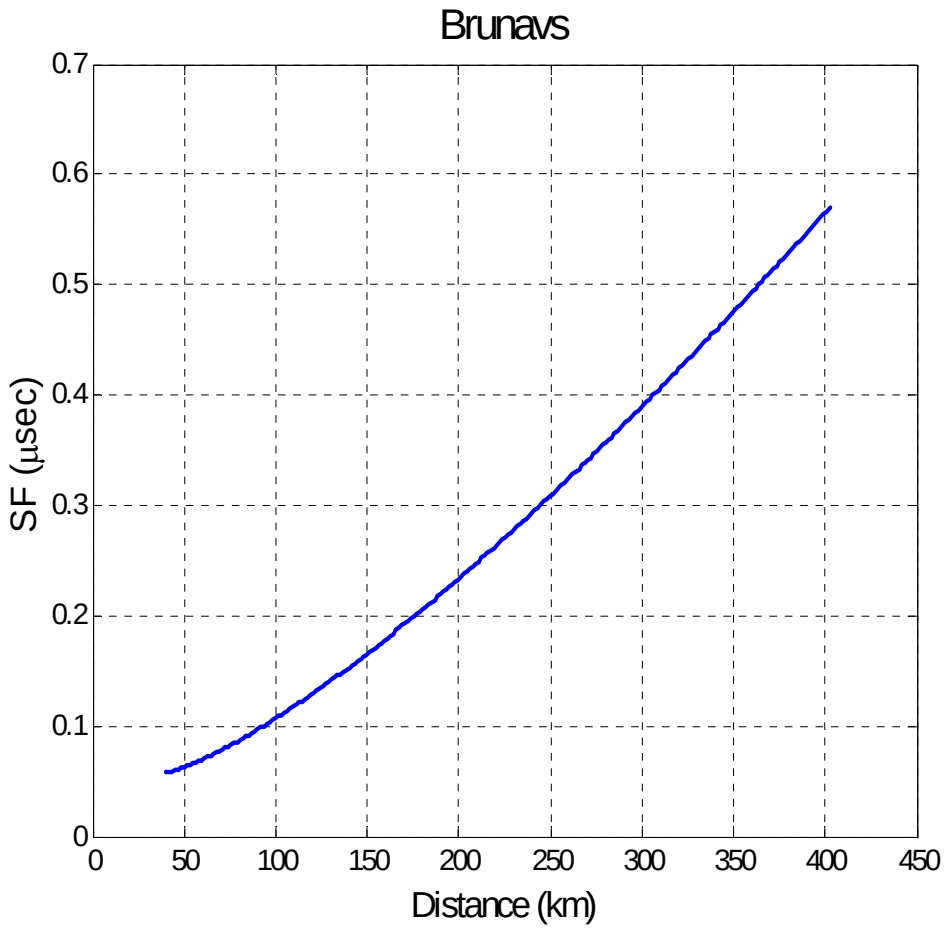
Harris Polynomial Discontinuity





$$SF(\mu\text{sec}) = \begin{cases} -.01142 + 0.00176d + .510483/d & d \le 100 \text{ statute mile} \\ -.40758 + 0.00346776d + 24.0305/d & d \ge 100 \text{ statute mile} \end{cases}$$

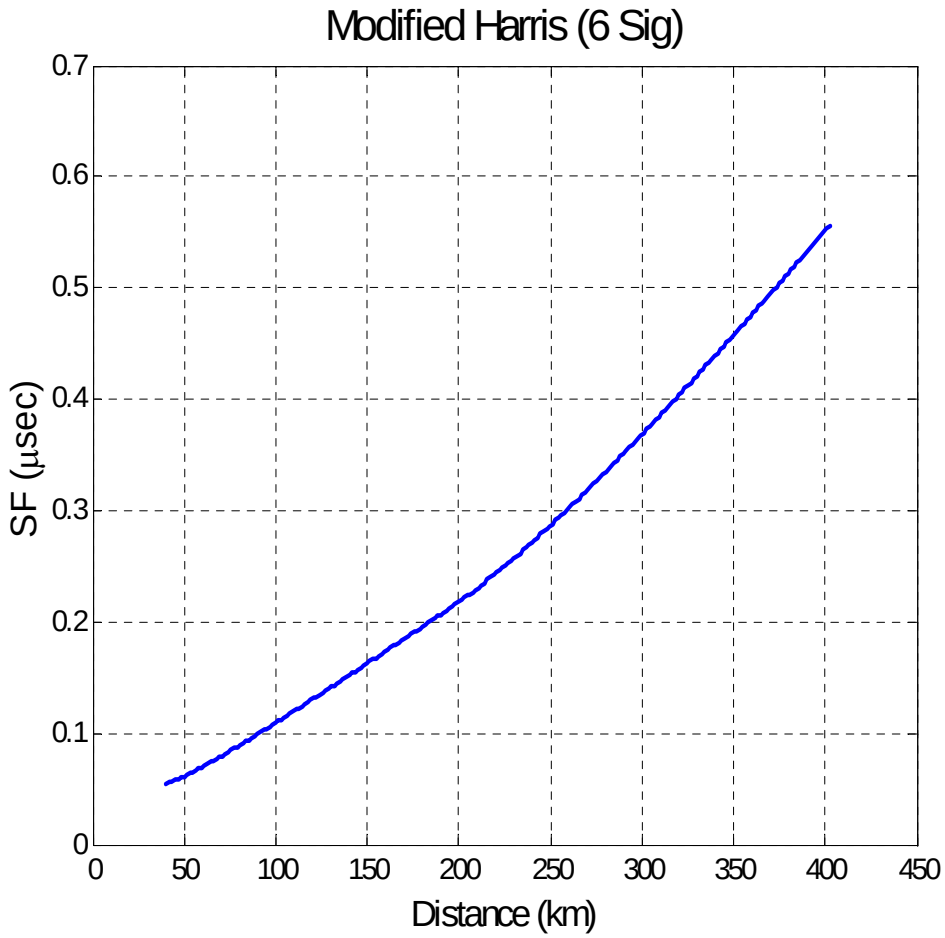
Brunavs



- Brunavs provides PF (alternate) + SF
- No discontinuities & continuous derivatives
- Values close to traditional Harris polynomials

$$Brunavs_{PF+SF}(m) = -111 + 98.2D + (13.0D + 113.0)e^{\frac{-D}{2}} + \frac{2.277}{D}$$

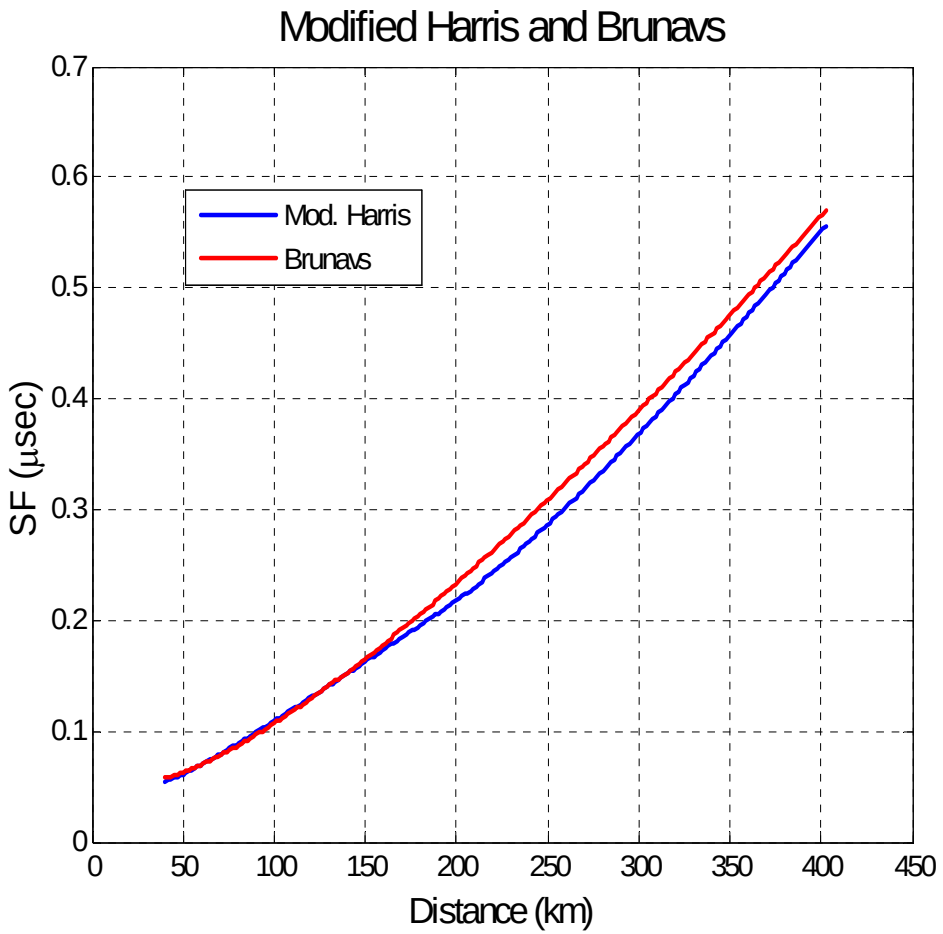
Modified Harris Polynominal



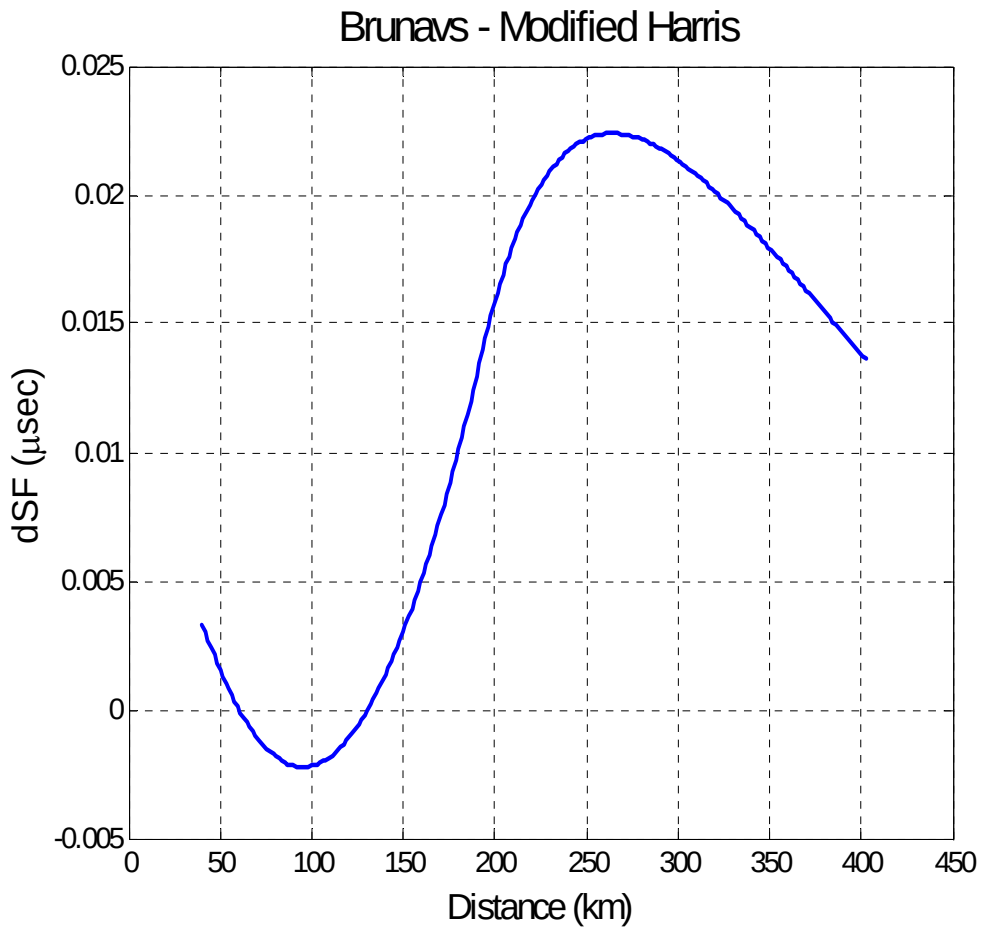
- Based on traditional Harris polynomial
- Eliminate discontinuity with minimum deviation from traditional
- 1st derivative close
  - 37.3 ns/km difference

$$SF(\sec) = \begin{cases} \left[-11.42 + 0.00112462d + {}^{821543}/_{d}\right] \bullet 10^{-9} & d \le 188.866km \\ \left[-407.58 + 0.00215477d + {}^{38897093}/_{d}\right] \bullet 10^{-9} & d \ge 188.866km \end{cases}$$

SF from Brunavs and Modified Harris

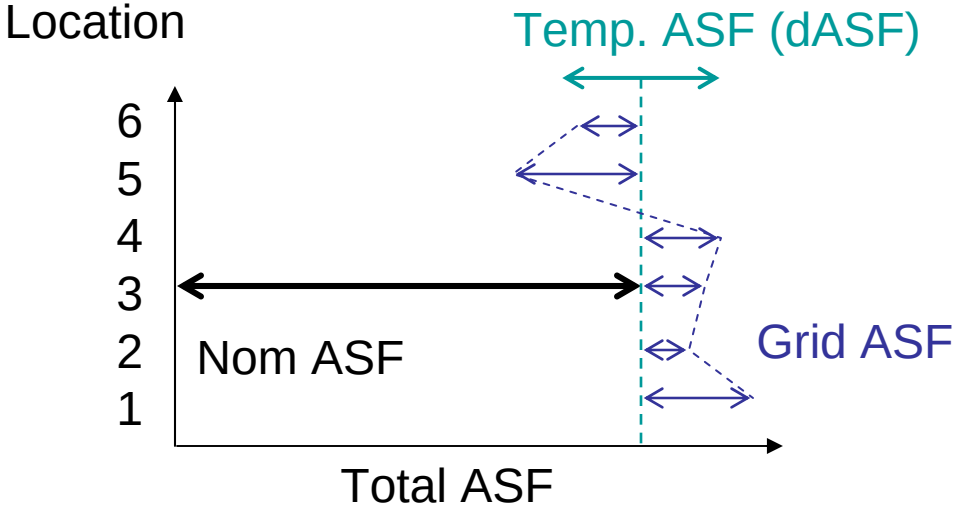


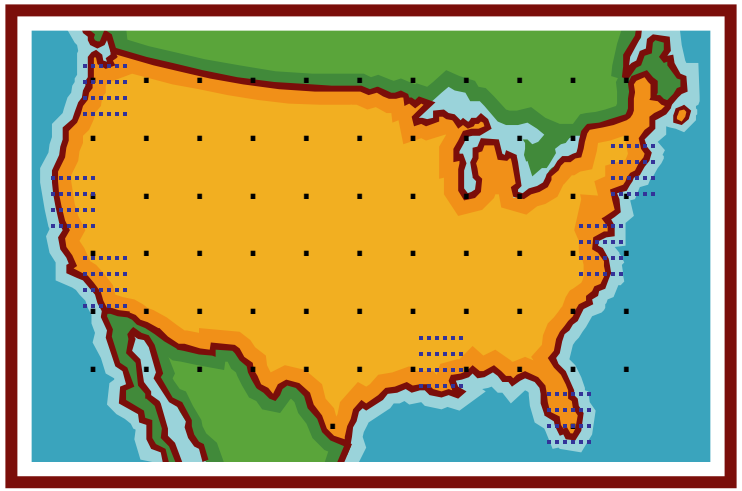
Modified Harris Polynomial (Equation & Difference)



- Difference between Brunavs & Modified Harris is small but significant
- Worst case is ~ 22 nsec or 6.6 m
  - cannot use either/or
- RTCM SC127 has decided to use Brunavs

ASF, ASF nominal, ASF grid





- Nominal ASF – nominal (mean value) of ASF at a region
  - Should be consistent with regional ASF values for smooth transition
- Grid ASF – the difference between the nominal ASF for the region and the actual ASF
  - Ideally measured at nearly the same time for all points in grid
  - Ideally chosen near the “midpoint” of the range of temporal variations
- Temp ASF – the difference between the true ASF and the nominal+grid ASF
  - Operationally = true ASF – (nominal ASF + grid ASF) for the monitor

Other Clarification

- SZC: “The positive zero crossing at 30 microseconds of a positively phase coded pulse on the antenna-current waveform. This zero crossing is phase-locked to the Loran-C station’s cesium time reference. The standard zero crossing is used as a timing reference for measurement of Loran signal specifications.”

- SSP: “The point on the Loran-pulse envelope that is 25 microseconds after the beginning of the pulse to which far-field field strength calculations or measurements are referenced. For the standard Loran pulse with 0.0 ECD, the amplitude at the standard sampling point is .506 times the peak amplitude.”

- Difference in power between SSP & SZC is 1.83 dB

Summary

- Need consistent definitions for MPS to ensure 10 m accuracy
- Specify η = 1.000338 for calculation of PF
- Change formula for SF from Loran signal spec for more continuous solution
- MPS compliant receiver will use nominal ASF values, ASF grids, and differential corrections to account for ASF

Acknowledgments & Disclaimer

- The authors gratefully acknowledge the support of the Federal Aviation Administration and Mitchell Narins under Cooperative Agreement 2000-G-028.

- RTCM SC127 participants and Robert Markle of RTCM

- 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.