Raw Data

to Improve

• Accuracy
• Integrity
• Availability

of Satellite Navigation

National Space-Based Positioning, Navigation, Timing Advisory Board

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VIGIL, Inc.
Phase Residuals

Residual (cm)

Time after start (sec)

SV Below Mask
Flight Test Results – Error Plots

Separation Vector Errors (East, North, Up) – Carrier-smoothed Code (T-20s) on

Relative Velocity Errors (East, North, Up)

Head-on Traffic
Overtaking Traffic
Crossing Traffic

RECEIVERS SEPARATED by SHORT BASELINE

Direction of Vector S from SV to mid-baseline

Ref. Location of
RCVR #0 (Origin)

O

| baseline R |

Offset Location of RCVR # 1

1

\[ 1_s = \frac{S}{|S|} \]

\[ B_0 B_1 = \text{RCVR biases} \]

\[ C_0 C_1 C_3 = \text{Clock errors} \]

\[ M = \text{Multipath} \]

\[ N = \text{Noise} \]

\[ Q = \text{Quantiz.} \]

Equations for pseudoranges - from -

OFFSET: \( (\mathbf{R} - \mathbf{S}) \cdot 1_s + \text{IONO} + \text{TROPO} + B_1 + C_1 - C_3 + M_1 + N_1 + Q_1 \)

ORIGIN: \( (-\mathbf{S}) \cdot 1_s + \text{IONO} + \text{TROPO} + B_0 + C_0 - C_3 + M_0 + N_0 + Q_0 \)

DIFF: \( \mathbf{R} \cdot 1_s + B + C + M + N + Q \)

\[ \Delta(\text{IONO}) = 0 \]

If \( \Delta(\text{TROPO}) \neq 0 \) adjust for altitude & wet/dry

Eliminate \( B \) & \( C \) by subtracting DIFFs from two SVs

Sync requirements \( \rightarrow \) knowledge (not control) of meas. timing
PERFORMANCE ISSUES

Error growth for 90 sec to closest approach:
ADSB: 10 m/sec * 90 sec = 900 meters
OhioU: 1 cm/sec * 90 sec < 1 meter

No ground station would be needed IF
RELATIVE differential operation
BUT recent panel gave no assurance

Decades-old advocacy
flight-validated and documented

Further – Ultratight (~20 dB) – why not routine
Reason: no "hooks"

More applications make the need more urgent
pedestrian nav, UAVs, ...
NO SUCH THING as a
• Latitude & Longitude meter
• Velocity vector meter

Ancient mariners knew, as we do – DEDUCE coordinate HISTORY from measurements

IONJ99 opens with 8 reasons for Measurements of Satnav (pseudorange, carrier phase) applicable to DME, eLoran, radar, ⋅⋅⋅ all

GPSWorld Dec 2009, pp. 8, 10, 12: "The industry can either adopt changes or continue to settle for performance levels at a minor fraction of the intrinsic capabilities available from our present and future systems."

Dixon et. al., "GNSS Vulnerabilities: Testing the Truth," Coordinates v VIII n3, March 2012, pp. 13-20: "Do we really need to wait for a catastrophe before taking action against GNSS vulnerabilities?"
LESS VULNERABILITY –
via LESS DEMAND for DATA

• In addition to (not in lieu of) smart-rf measures:
  • IMU aiding (cm/sec even with old MotionPak)
  • Single measurement RAIM

• Interoperability/Interchangeability → InterFACE
  – with all sensors – easy

• Optimize dynamics as well as position

• Recognize that dynamics often warrant priority

• vanGraas/Pelgrum road test

• By all means, backup -- and, still -- use GNSS when available, even fragmentary

• No more "GPS vacation"
1-sec Changes in Carrier Phase

- Ambiguity forever OK
- No mask
- Discontinuities OK
- Immediate reacq
- Flight validated
- Any channel any constellation
- Insensitive to
  - SV mislocation
  - nonuniform ellipsoid models
  - nonuniform time ref
- Geometry benefit
CURRENT POPULAR APPROACHES

Full fix + RAIM "on silver platter" every time
No access to data that would enable flexibility
No hooks to enable ultratight coupling
Proprietary
Integrity monitor + tight coupling + diff:
    INTERNAL (if at all)
EVERY CHANGE INCURS FULL COST
PARTIAL HISTORY of ADVOCACY

NAECON 77
JLFvG GPS-90
NAECON 93
AEEC
GPSWorld, InsideGNSS
BigBook
C-A seminar, ION-GPS-2000
FAA/ SC 186
ION (e.g., IONJ Fall `99)
Coordinates zine
IJUSENG – v1 n1, pages 1-8
YouTube
RECOMMENDATIONS

Raw data across-the-board
Keep the good while rejecting the bad
Every combination federated + integrated available in parallel
Exploit well-known capabilities
Capitalize on less-known innovations
ENORMOUS gains performance + economy + flexibility
The best humanly possible strategy is to deliver whatever performance is reachable from all available information, incomplete as it may be. For decades it has been feasible to combine intermittent partial data – of different types at varying accuracies with different sensitivities from different directions at different times – and extract all benefit offered. Decisions adopted herein offer no more and no less than that.

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PDFS


COLUMNS AND MANUSCRIPTS

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