1998: A YEAR OF INNOVATION IN (THE) GPS WORLD

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University of New Brunswick

Invited presentation at the Association of New Brunswick Land Surveyors
Annual General Meeting, Fredericton, N.B., 23 January 1999

GPS Accuracy: Lies, Damned Lies, and Statistics

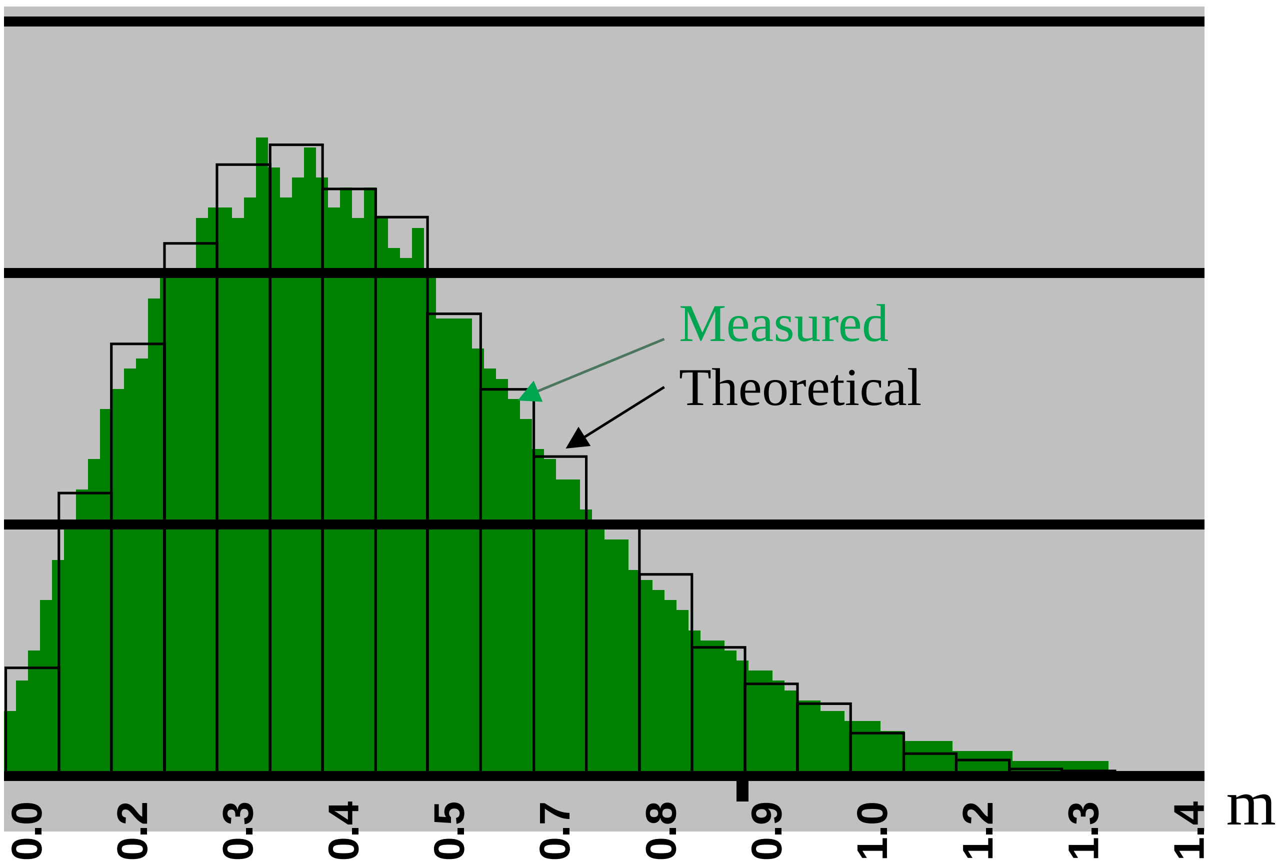
F. van Diggelen, Ashtech, Inc.

- Popular accuracy measures
  - r.m.s. (vertical)
  - circular error probable
  - r.m.s. (horizontal)
  - R95 (horizontal 95%)
  - 2 d.r.m.s.
  - r.m.s. (3D)
  - spherical error probable
- Common misconceptions
  - r.m.s. precisely equals 1 sigma
  - 2 d.r.m.s. means "two-dimensional r.m.s."
  - 2 d.r.m.s. is exactly equivalent to a 95% probability level
  - r.m.s. is perfectly comparable with a 68% probability level
  - the error distribution really is Gaussian

Accuracy Measures

Dimensions	Accuracy measure	Probability	Typical usage (dimensions)
1	r.m.s.	68	vertical
2	CEP	50	horizontal
2	r.m.s.	63-68	horizontal
2	R95	95	horizontal
2	2 d.r.m.s.	95-98	horizontal
3	r.m.s.	61-68	3D
3	SEP	50	3D

January, cont'd.



Measured and theoretical DGPS horizontal errors from 2 million data points

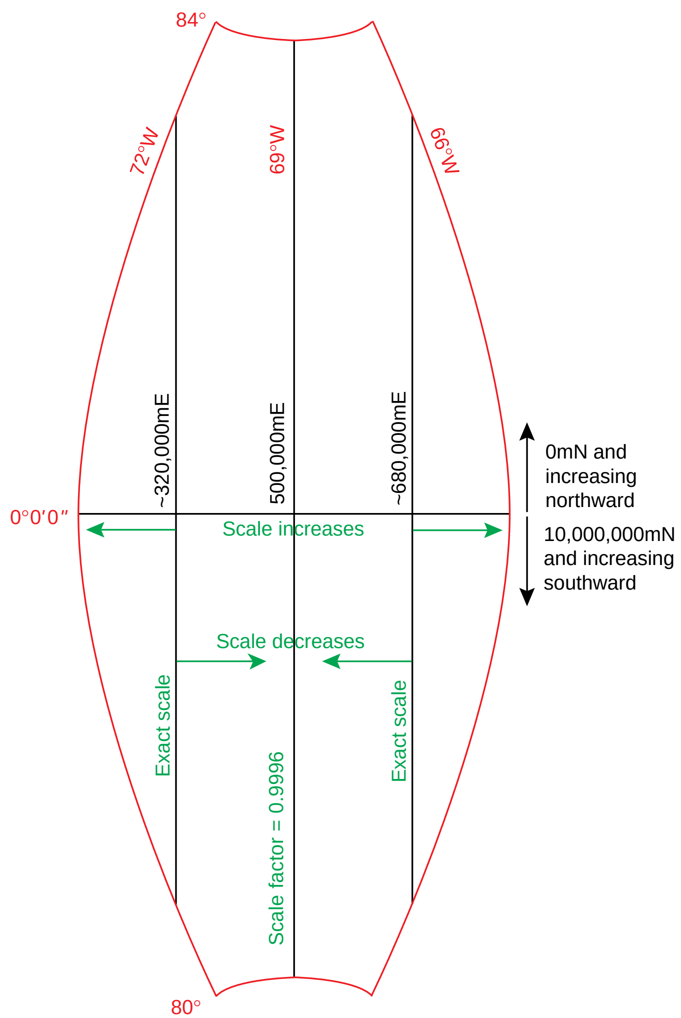
CEP = 42 cm
r.m.s. = 52 cm
R95 = 91 cm
2 d.r.m.s. = 104 cm

The UTM Grid System

R.B. Langley, UNB

- Coordinates and Projections
- Mercator's World
  - Adopting the ellipsoid
- A Universal Projection
  - UTM
  - The grid
    - British National Grid
    - 500 km squares → 100 km squares → x,y coordinates
    - Tower of London: TQ 336805 or 33.6 km E, 80.5 km N of SW corner of TQ
  - Military grid reference
    - UNB Gillin Hall ref. point: (WGS 84) 682,725 m E; 5,091,225 m N, zone 19T = MGRS 19TFL8272591225

February, cont'd.



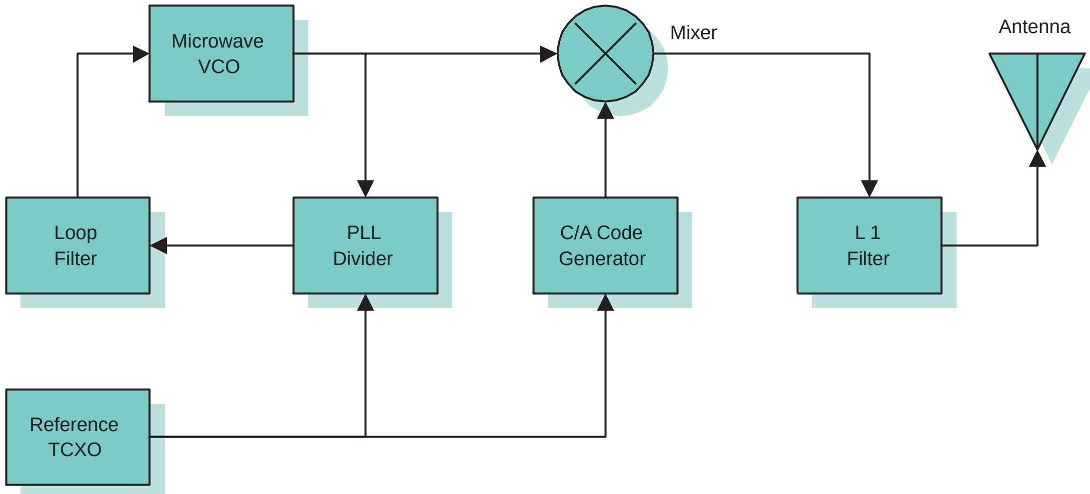
UTM zone 19 extends from 86° to 72° west longitude. As with all UTM zones, the scale factor is 0.9996 on the central meridian and true (unity) on two slightly curved lines approximately 180 km to either side. The shape of the zone has been exaggerated for clarity.

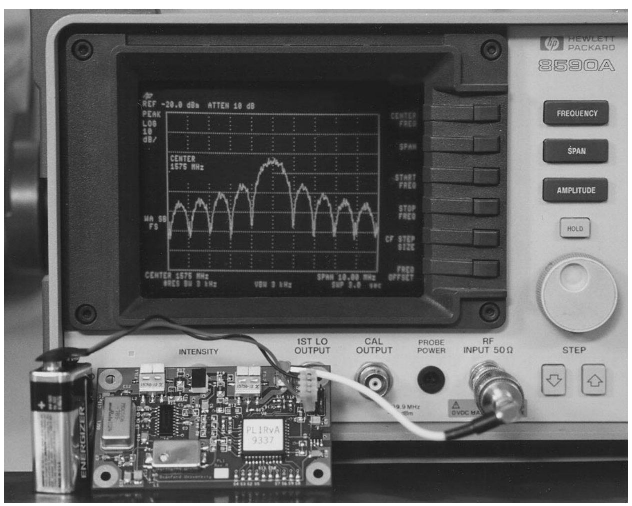
Pseudolites: Enhancing GPS with Ground-based Transmitters

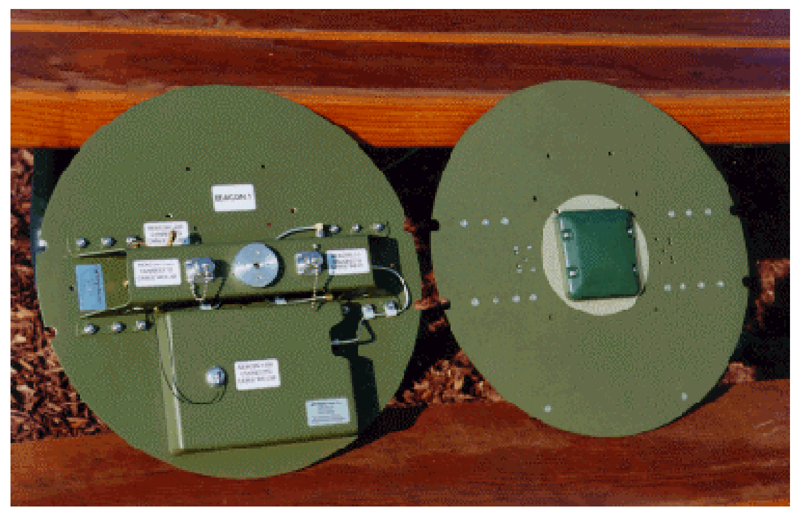
S. Cobb and M. O'Connor, Integrinautics Corp.

- What is a Pseudolite?
- Primary Pseudolite Uses
  - Code-based ranging augmentation
  - Code-phase differential ranging
  - Carrier-phase differential ranging
    - Ambiguity resolution
  - Indoor pseudolites
- The Near-far Problem
  - Signal pulsing
  - P-code use

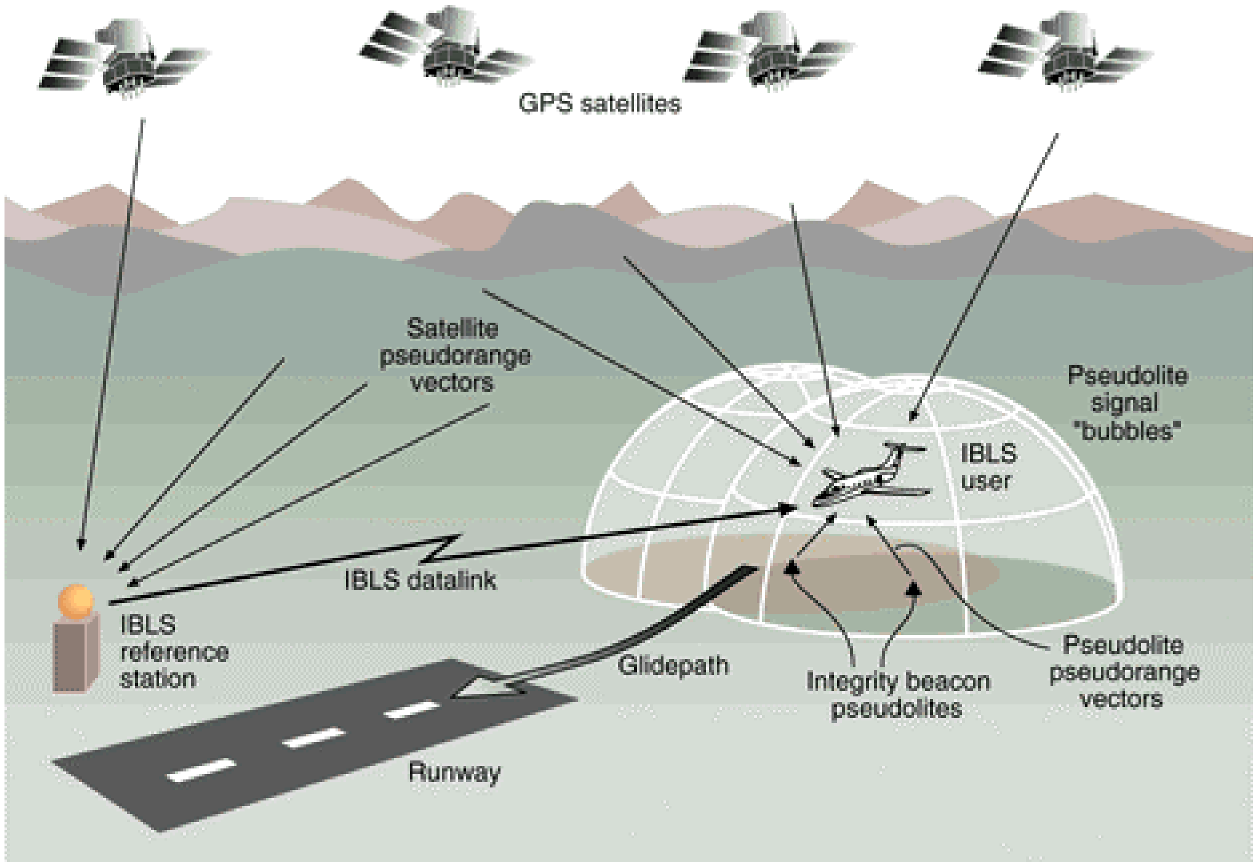
March, cont'd.


Microwave VCO
Mixer
Antenna
Loop Filter
PLL Divider
C/A Code Generator
L 1 Filter
Reference TCXO


8590A
FREQUENCY
SPAN
AMPLITUDE
INTENSITY
1ST LO OUTPUT
CAL OUTPUT
PROBE POWER
RF INPUT 50 Ω
STEP



March, cont'd.



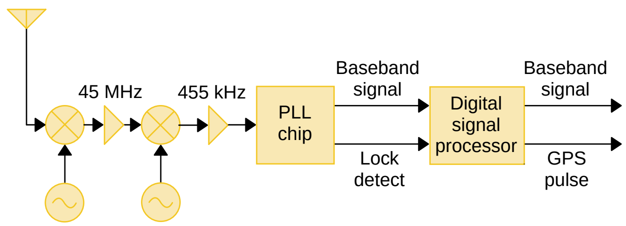
Integrity Beacon Landing System

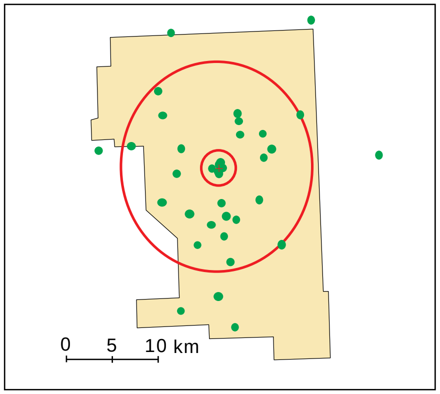
Cellular Telephone Positioning Using GPS Time Synchronization

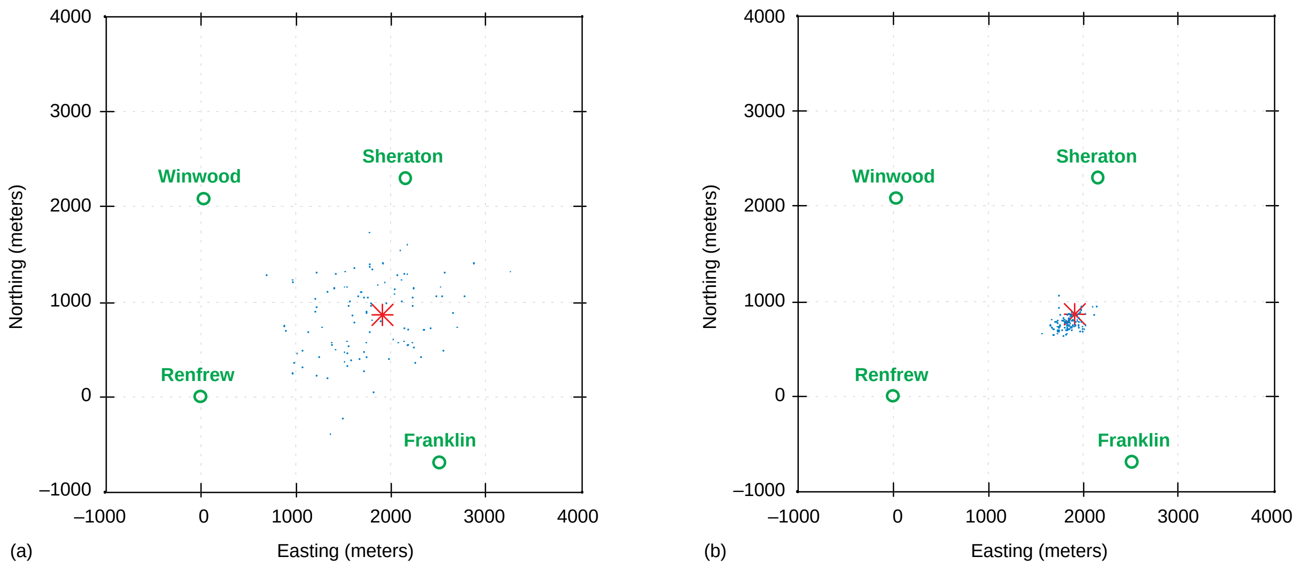
R. Klukas, Cell-Loc, Inc. and G. Lachapelle and M. Fattouche, U. of C.

- E-911 Cell Phone Positioning
  - FCC requires horizontal cell phone position to 125 m d.r.m.s. by 2001
- TOA Estimation
  - A system to horizontally position cellular telephones using analogue AMPS (Advanced Mobile Phone Service)
- System Description
  - Time tagging with GPS
  - Full correlation with MUSIC (Multiple Signal Identification and Classification)
  - Position estimation
- Field Tests
  - Simulations used approximately 40 sites within a Calgary cellular network; field tests with 4 sites

April, cont'd.


45 MHz
455 kHz
PLL chip
Baseband signal
Lock detect
Digital signal processor
Baseband signal
GPS pulse

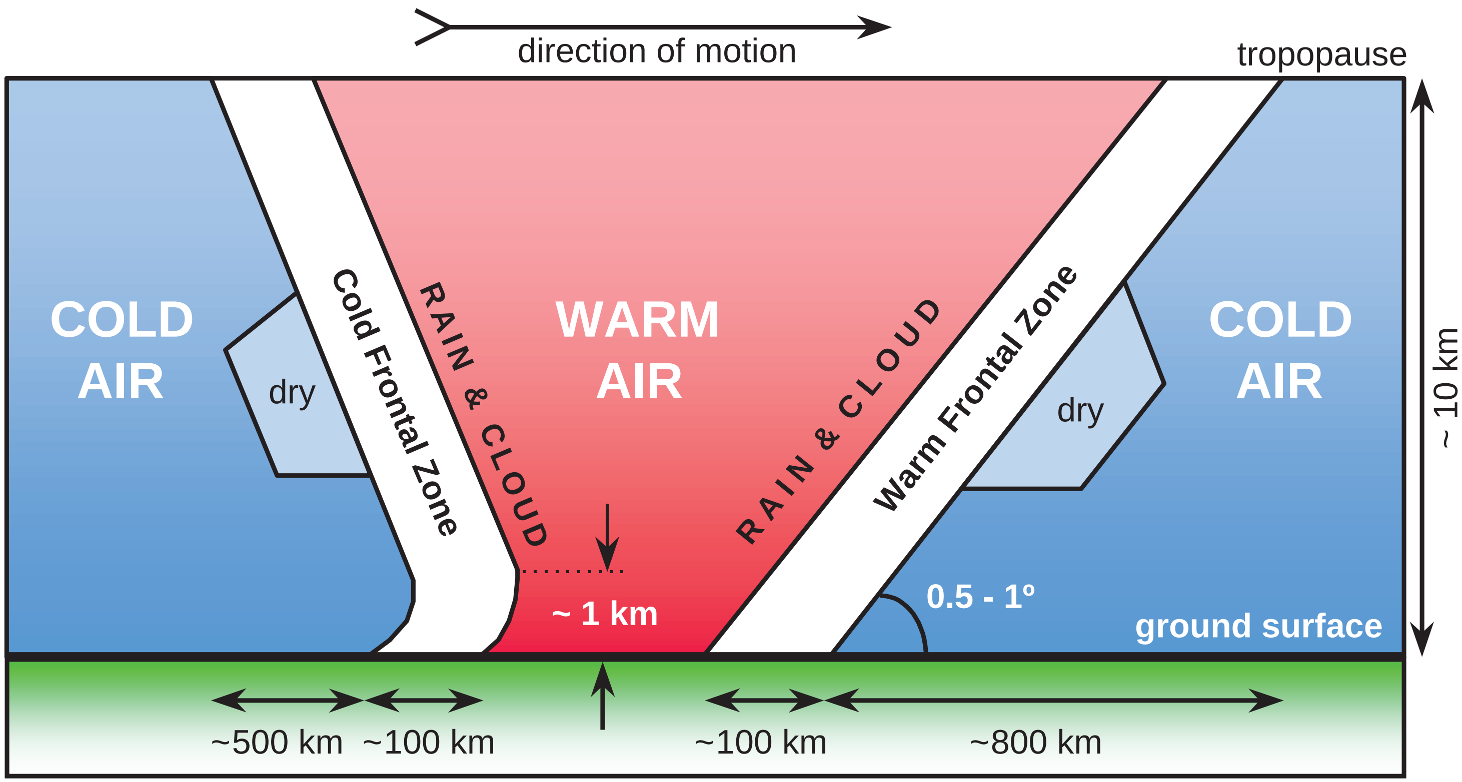

0 5 10 km


Winwood
Sheraton
Renfrew
Franklin
Northing (meters)
Easting (meters)
(a)
(b)

The Effect of Weather Fronts on GPS Measurements

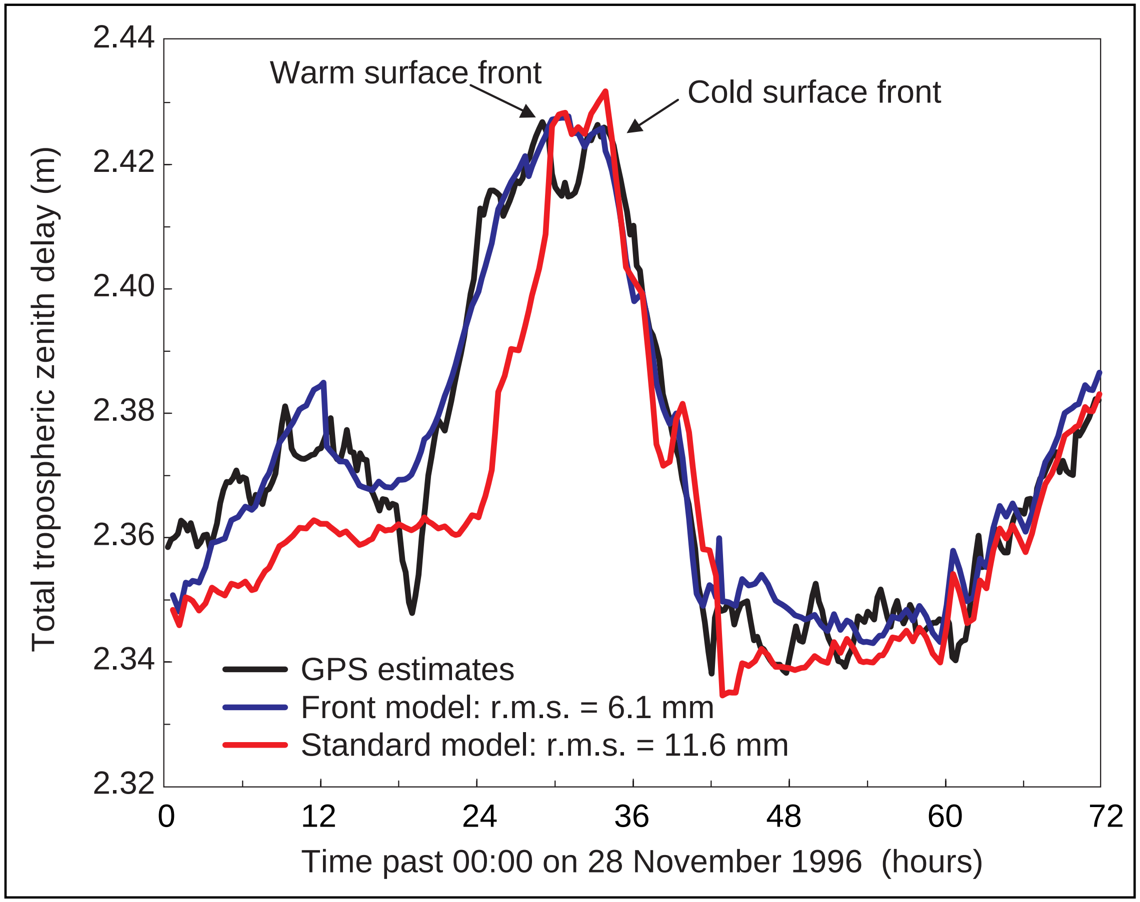
T. Gregorius and G. Blewitt, Univ. of Newcastle upon Tyne

- Atmospheric Delay
- The Positioning Effect
  - Height error = 3 x tropo delay error
- What is a Weather Front?
- Delay Estimation Models
- Fronts and GPS Precision
  - Improving repeatability
  - Vertical velocity
  - The horizontal factor
- Remedies and Possibilities
  - Radiosondes, satellites (GPS/MET), data editing



direction of motion
tropopause
COLD AIR
dry
Cold Frontal Zone
RAIN & CLOUD
WARM AIR
RAIN & CLOUD
Warm Frontal Zone
dry
COLD AIR
~ 10 km
~ 1 km
0.5 - 1º
ground surface
~500 km
~100 km
~100 km
~800 km

May, cont'd.



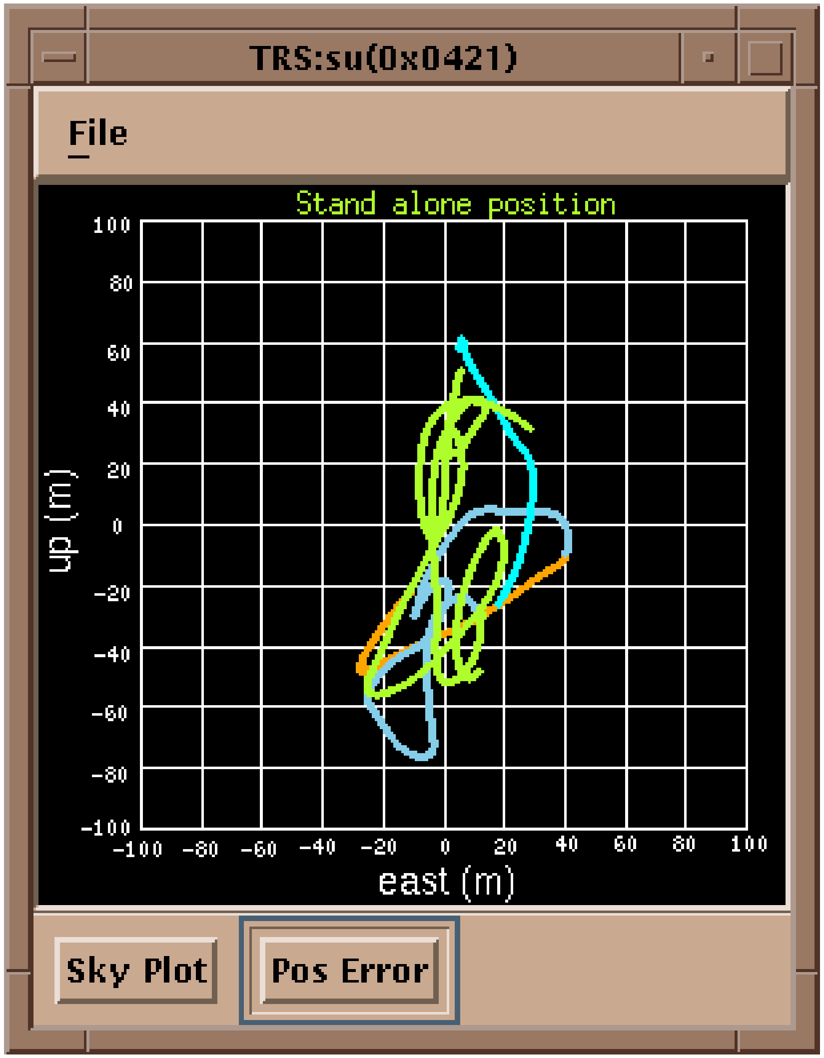
2.44
2.42
2.40
2.38
2.36
2.34
2.32
Total tropospheric zenith delay (m)
Warm surface front
Cold surface front
GPS estimates
Front model: r.m.s. = 6.1 mm
Standard model: r.m.s. = 11.6 mm
0
12
24
36
48
60
72
Time past 00:00 on 28 November 1996 (hours)

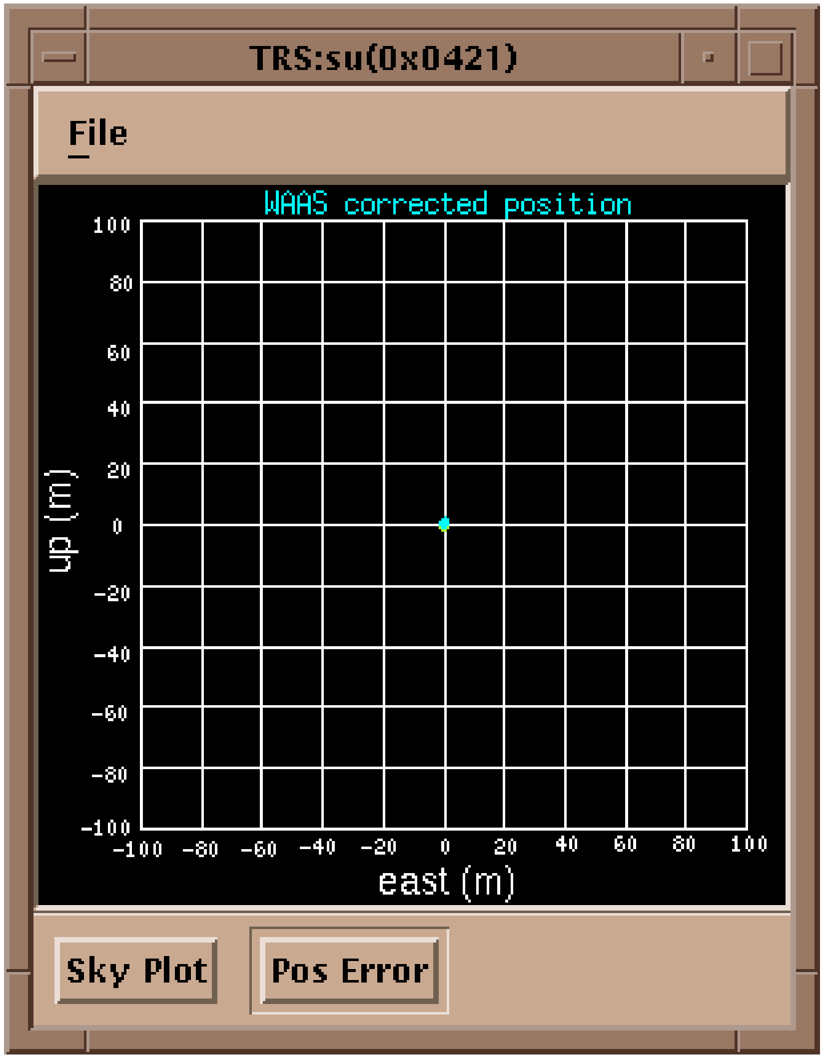
The NSTB: A Stepping Stone to WAAS

Andrew Hanson, Stanford University

- WAAS in Practice
  - Reference stations
  - Error models
- The Stanford Connection
- WAAS Metrics
  - Accuracy
  - Integrity
  - Availability
- Flight Testing

June, cont'd.


TRS:su(0x0421)
File
Stand alone position
up (m)
east (m)
Sky Plot
Pos Error

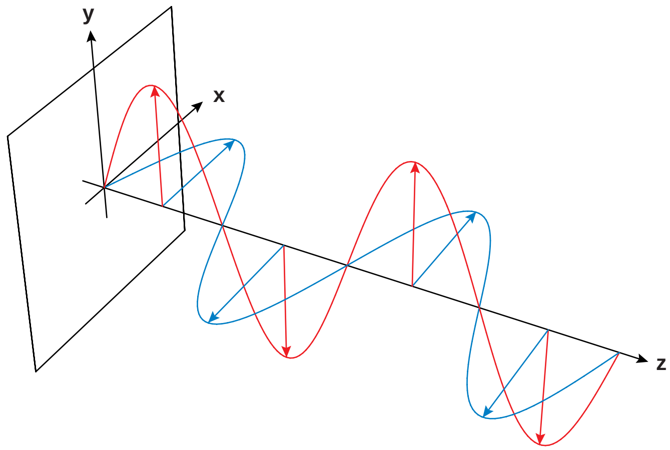

TRS:su(0x0421)
File
WAAS corrected position
up (m)
east (m)
Sky Plot
Pos Error

A Primer on GPS Antennas

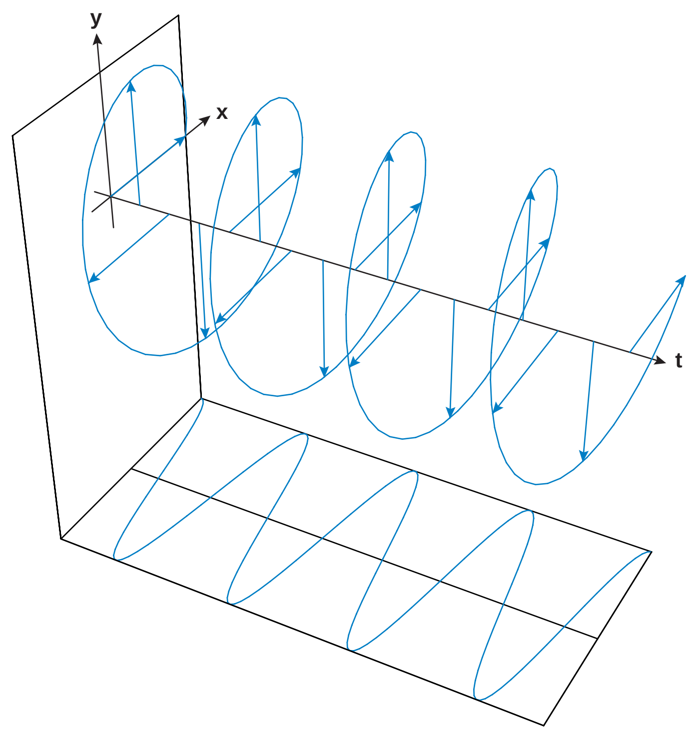
R.B. Langley, UNB

- Fields and Waves
- Antenna Characteristics
  - Axial ratio
  - Impedance
  - Standing Wave Ratio
  - Bandwidth
  - Gain pattern
  - Ground planes
  - Phase-centre variation
- Low Noise Preamp
- Transmission Lines

July, cont'd.

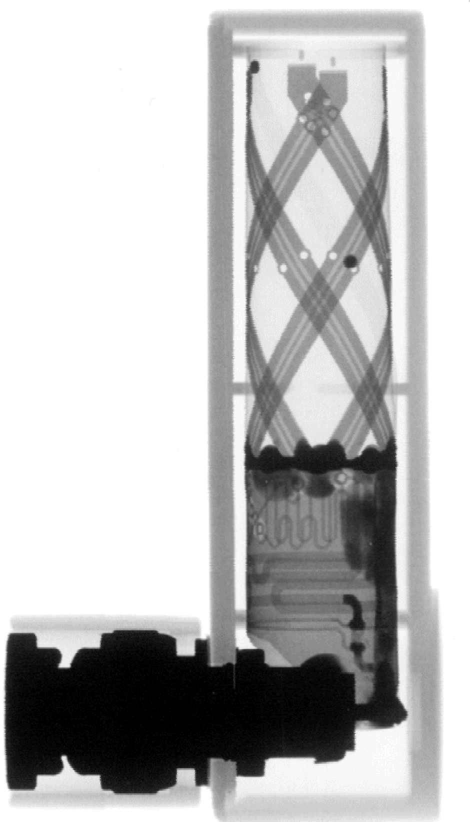


At a fixed point in space, the electric field vector of a right-hand circularly polarized wave rotates clockwise as seen from the wave's source.

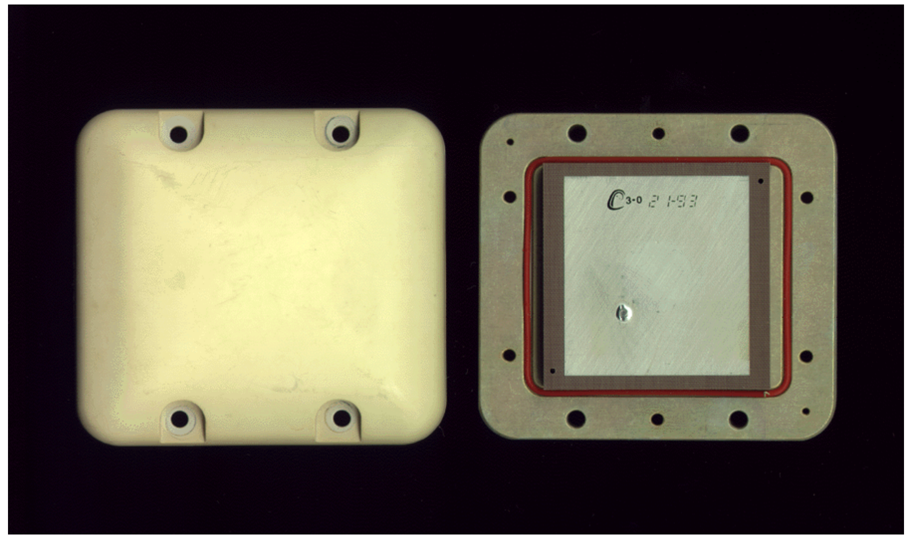


The electric and magnetic fields are transverse to the direction of propagation, and the fields are mutually perpendicular.

July, cont'd.



Quadrifilar helix



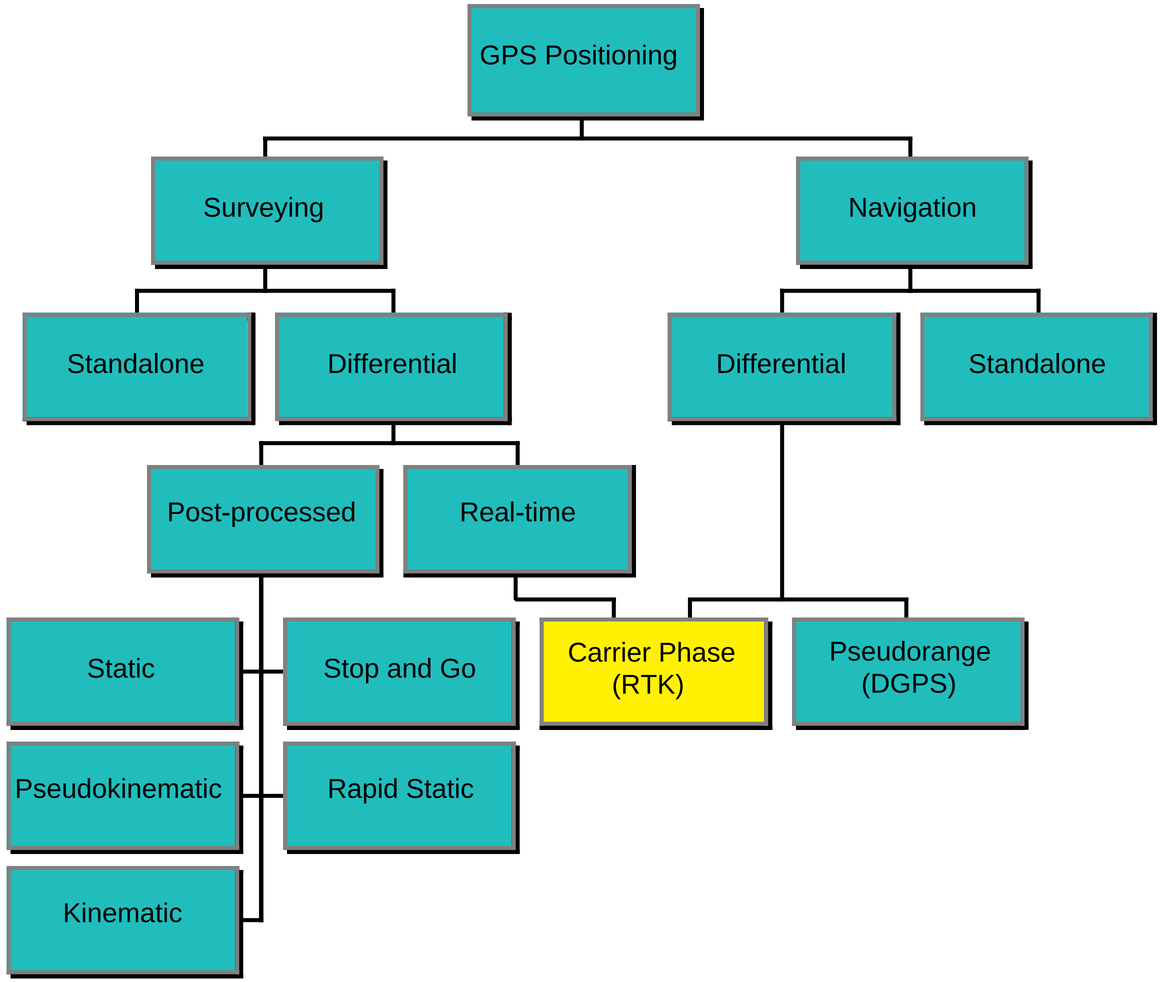
Microstrip patch

RTK GPS

R.B. Langley, UNB

- A Fix on Accuracy
- Carrier-phase Positioning
  - Post-processed
  - Real time
  - Correction message formats: RTCM SC-104
- RTK System Architecture
- The Data Link
  - Propagation distances; path loss; viability
- RTK Solutions
  - OTF
  - GLONASS

September, cont'd.



September, cont'd.

RTK Hardware

GPS MATLAB Toolbox Review

A.K. Tetewsky and A. Soltz, Draper Laboratory

- What is MATLAB?
- The Toolboxes
  - GNSS Toolbox, Orion Dynamics and Control Corp.
  - Constellation Toolbox, Constell, Inc.
  - SatNav Toolbox, GPSoft LLC
  - GPS Signal Simulator Toolbox, Navsys Corp.
- Simulation Challenges
  - Scenario simulation; GPS measurement selection, navigation accuracy, algorithm development; fault monitoring; reading recorded data; total receiver simulation; presentation graphics
- Experiences
- Suggestions

October, cont'd.

Toolbox Overview

	Orion GNSS Toolbox 2.05	Constell Constellation Toolbox 3.02	GPSoft SatNav Toolbox v. Feb 98	Navsys GPS Signal Simulation Toolbox
MATLAB version	5.x	5.x	4.2c, 5.x	4.2C
Platforms	PC, can coerce for Mac/Unix	PC, can coerce for Mac/Unix	PC, can coerce for Mac/Unix	PC, can coerce for Mac/Unix
Library m-files	68	68	30 m files	118
Tutorial m-files	7	7	26 m files	9
Demo m-files	34	34	x	11
Space (32 kB blocksize)	2.88 MB	2.88 MB	266 kB	1.29 MB
Support	1 year, free, e-mail	1 year, free, e-mail, web	1 year, free, email	1 year, free, e-mail
Copyright	repay each copy	repay each copy	repay each copy	unknown
Upgrades	call	call	call	call
	(tutorial and demos were in separate directories)	(tutorial and demos were in separate directories)	(all in one directory, examples started with *ex*)	(three subdirectories: *geo* for coordinates, *sat* for satellites, and *signal* for the rest)

October, cont'd.

GPS Measurement Selection, Navigation Accuracy, and Algorithm Development

	Orion GNSS Toolbox 2.05		Constell Constellation Toolbox 3.02		GPSoft SatNav Toolbox v. Feb 98		Navsys GPS Signal Simulation Toolbox	
Meas Select Tools								
DOPs	Y-WD	S-TM	Y-WD	S-TM	Y		Y	
Nav Fix Tools								
Point pos & time	Y WD	S-TM	Y-WD	S-TM	Y	S-TM		
Point vel & drift	Y WD	S-TM	Y-WD	S-TM	Y	S-TM		
Scalar LADGPS	Y	S-TM	Y	S-TM	Y	S-TM		
Carrier-phase smooth					Y			
Single-diff CDGPS	Y		Y		Y			
Doubl-diff CDGPS	Y		Y		Y	S		
K.F. PV PVT model					Y	S-TM*		

Note: Subcategories that no vendors currently support but are of interest to the community include weighted DOP; robust DOP; vector WADGPS; attitude fix; carrier phase K.F. PV; and K.F.+sensors.

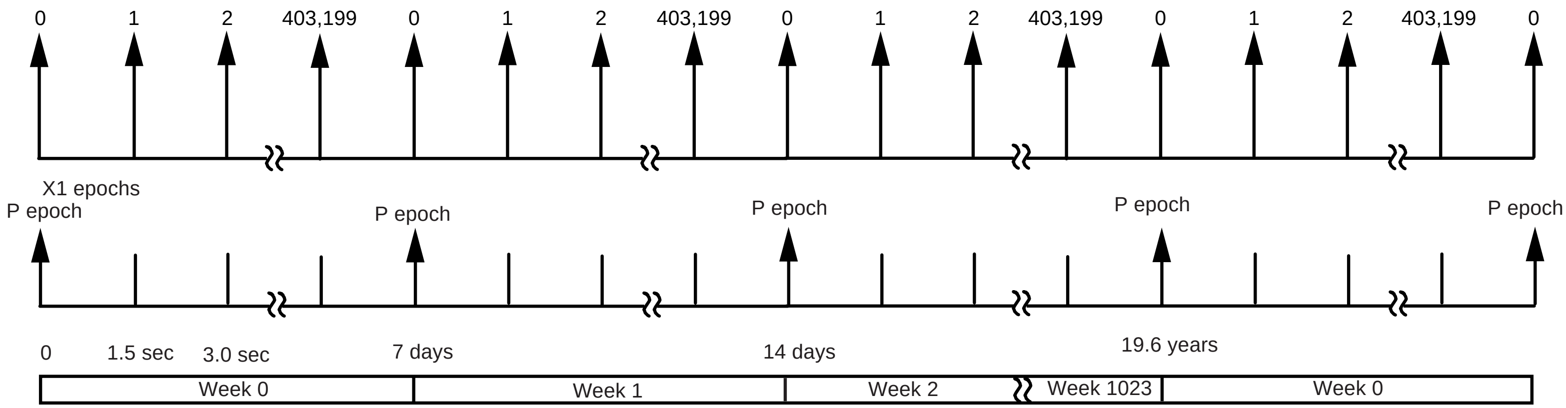
* available on request

The GPS End-of-Week Rollover

R.B. Langley, UNB

- GPS Time
  - GPS Time = UTC + 13 seconds + δ
  - Z Count
  - Time of week
- The Rollover
  - Similar to Y2K problems
  - On 21/22 August 1999, GPS Week 1023 is followed by Week 0
- Receiver Effects
  - Currently marketed receivers shouldn't be affected
  - For some, a firmware upgrade is available
  - Noncompliant: wrong date, wrong satellite coordinates, refuse to compute positions, long startup times, fail to lock onto satellites

November, cont'd.



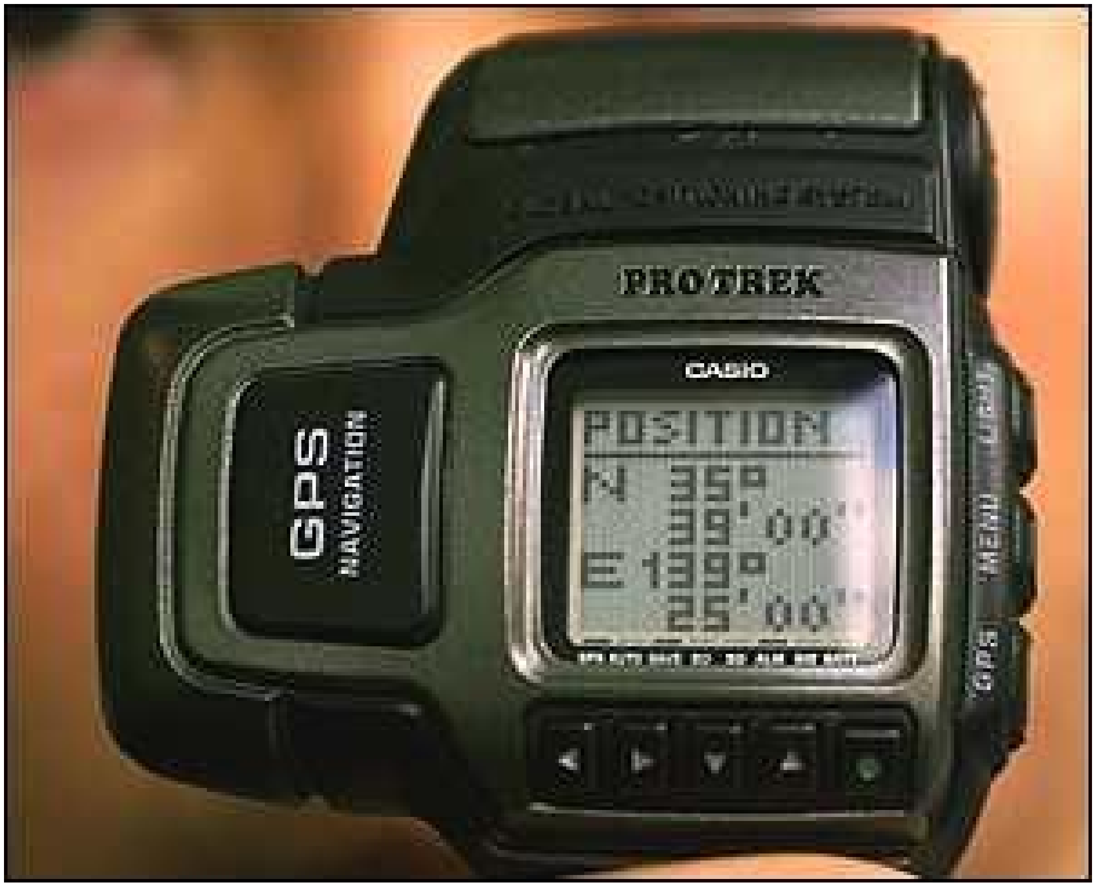
The inherent, fundamental GPS timing unit is the 1.5-second repetition period of the P-code's X1 subcode. The P-code is reset every week or 403,200 X1 epochs. The GPS week number count is reset every 1024 weeks or approximately 19.6 years.

Start and end dates of the first three GPS week cycles.

GPS Week Cycle	***Start of Week 0***	***End of Week 1023***
1	January 6, 1980 (44244)	August 21, 1999 (51411)
2	August 22, 1999 (51412)	April 6, 2019 (58579)
3	April 7, 2019 (58580)	November 20, 2038 (65747)

(The numbers in parentheses are the corresponding modified Julian dates.)

1999


PROTREK
CASIO
POSITION
N 35°
39'00"
E 139°
25'00"
GPS
NAVIGATION
MENU
GPS