International Testing Perspective
CGSIC
Portland, OR
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“The View From Here”

- Commercial / consumer users are most demanding
  - Ubiquity, including indoors / deep urban
  - Perfect performance, always
- GPS-only → Multi-GNSS
- Integrated GNSS with augmentation

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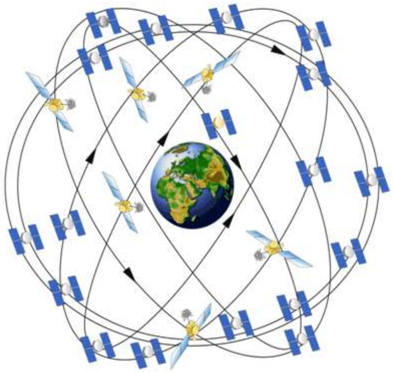
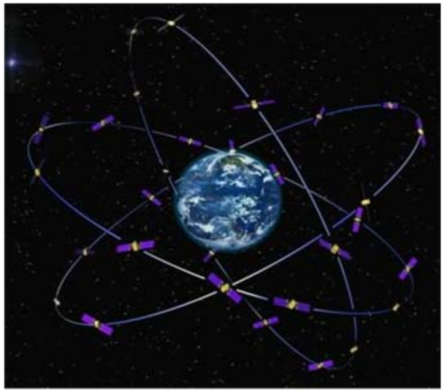
Discussion of Some Key Developments

- Multi-GNSS + Augmentation
- Wi-Fi positioning
- Solar maximum and atmospheric scintillation impacts

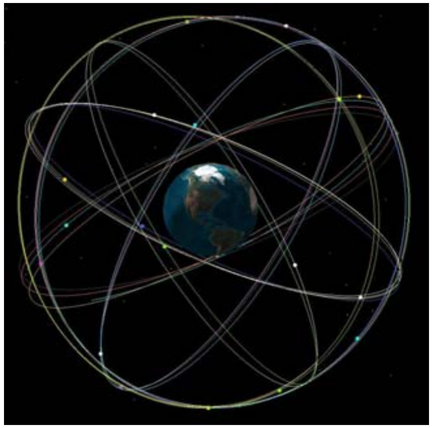
Multi-GNSS: New Possibilities



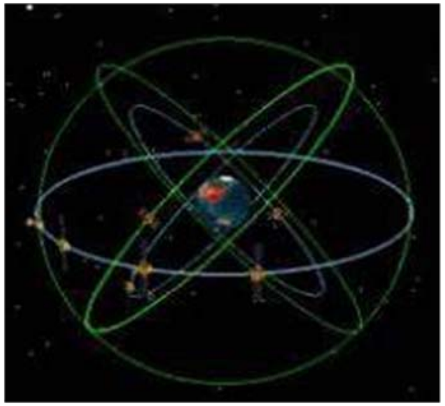
GPS



Galileo

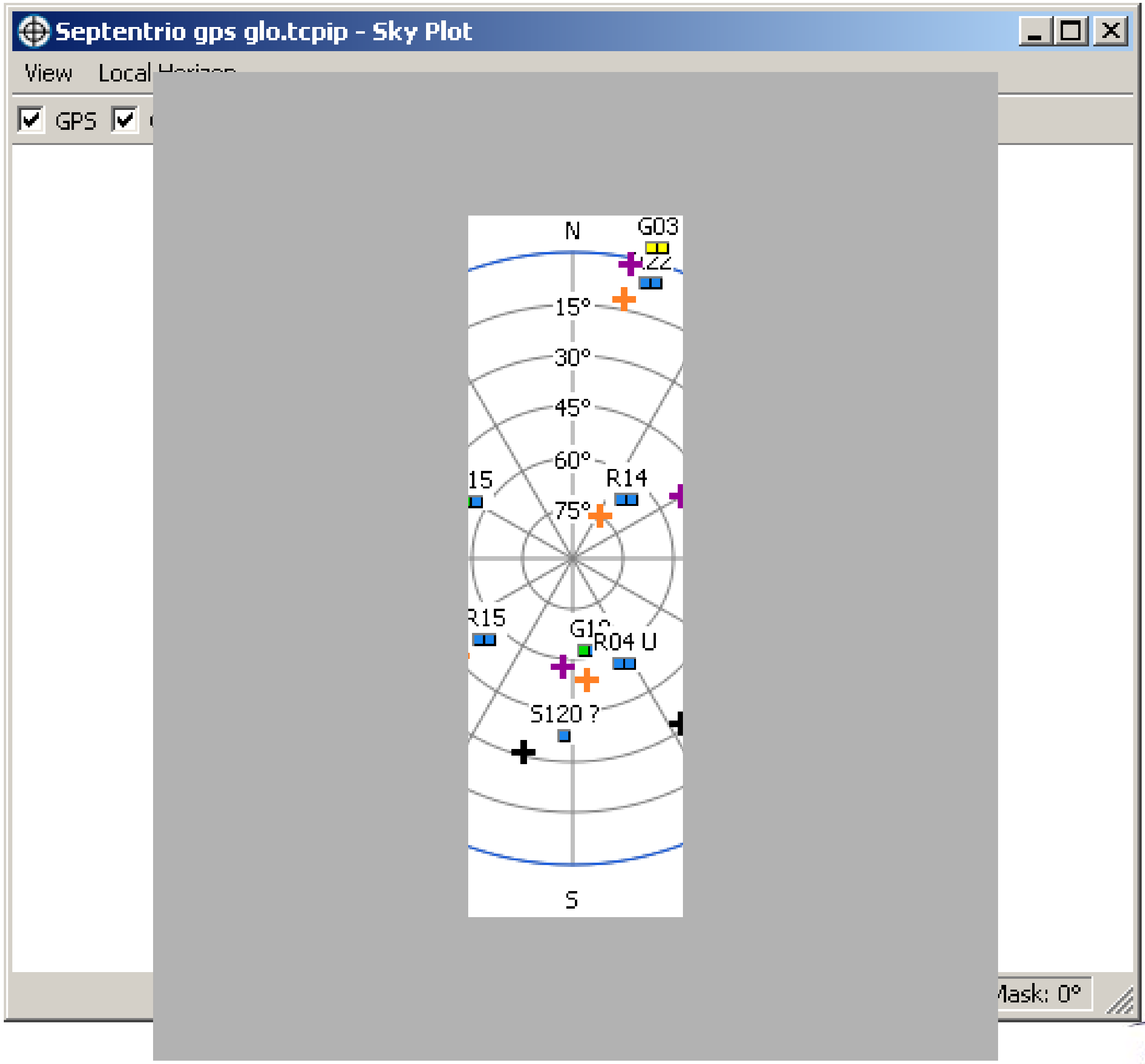


GLONASS



Compass

GPS + GLONASS + SBAS at offices in UK



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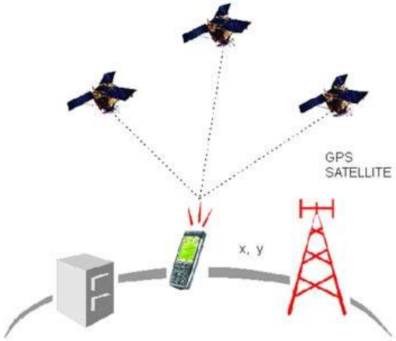
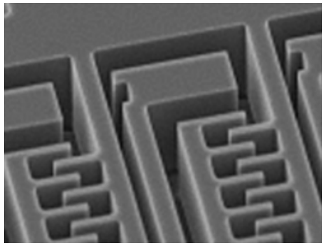
Looking Ahead …

Augmentation

QZSS



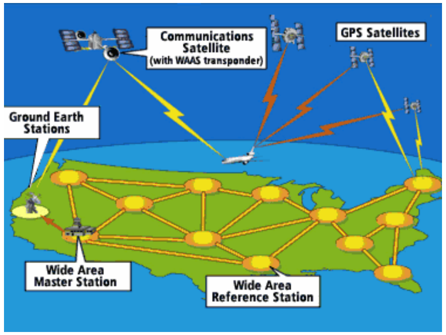
A-GPS



MEMS

DR
(eg. ABS sensors)

Space-Based Augmentation Systems

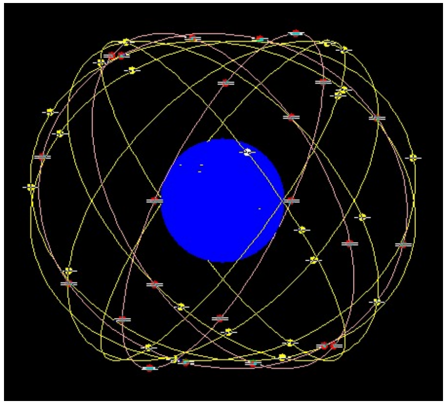


e.g. WAAS

Commercial / Consumer GNSS

- GPS L1 C/A code only is not enough in future
- Most Rx will be at least multi-GNSS at L1 frequency
- Augmentation and/or DR will be used in most systems
- Over time, receivers will be multi frequency for improved accuracy

Major implications for GNSS receiver, system and application developers



GPS + GLONASS

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Wi-Fi Positioning
Overview
Status

Solving the Indoor Problem

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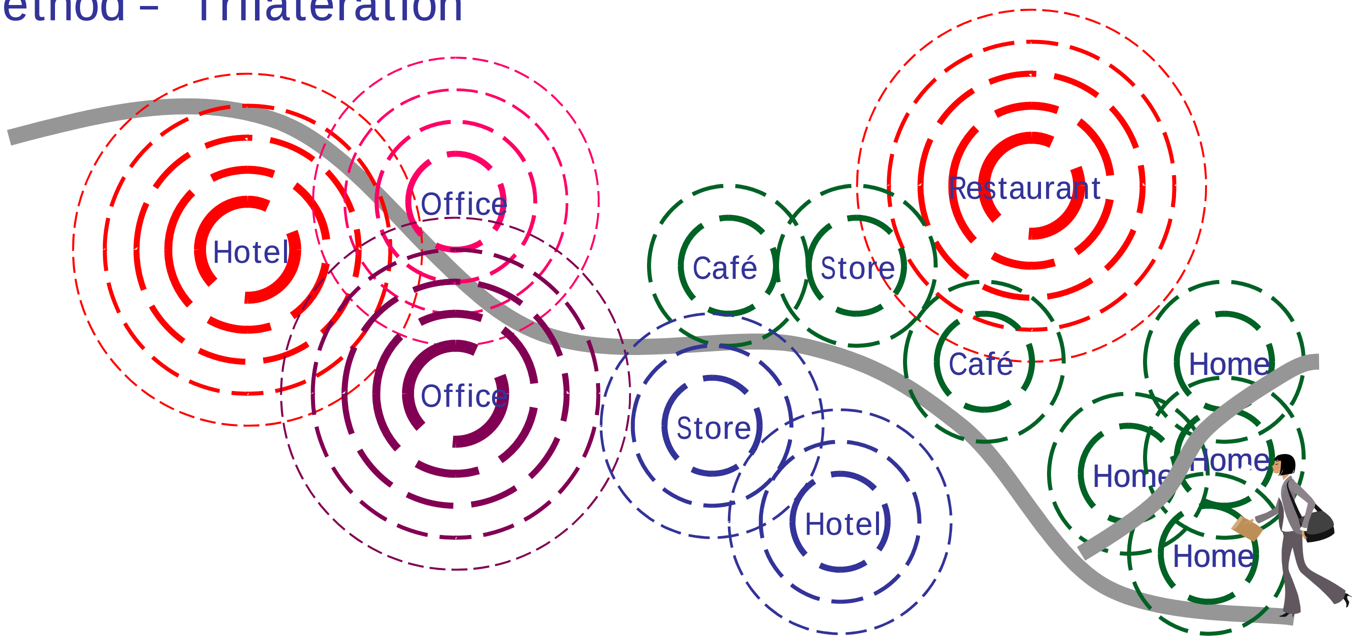
Wi-Fi Mobile Device Positioning Concept

- Use Wi-Fi Access Points (APs, "Hotspots") to determine mobile device location
  - A) Method – 'Fingerprinting' or 'Pattern Recognition'
  - B) Method – 'Trilateration'



- Both methods involve generation and maintenance of a database of observation-based 'Hotspot' data

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WiFi Positioning - 'Fingerprinting' Principles #1

- Survey the area of interest
  - Record accurate location at regular intervals
    - Often GPS and Inertial
  - At each location scan for WLAN AP signals
  - Record characteristics of each signal at each location
    - MAC Address as a minimum
      - 100% unique for each Access Point
    - Optionally SSID, Channel frequency, 802.11 type
    - Optionally record the received signal strength (RSSI)
  - Store observations in a database
- Update database periodically
  - New survey
  - User observations
      - Self-healing principle – see later

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WiFi Positioning - 'Fingerprinting' Principles #2

- To locate a user
  - User device (UE) scans for WLAN signals
    - MAC Address is primary data
  - UE passes observations to Positioning Server
    - Located in network – UE-assisted
    - Located in device – UE-based
      - Download 'local' database using approximate Cell-ID location
  - Positioning Server finds "Best Match"
      - Compares observations with previous observations stored in database
      - Can use RSSI to choose between multiple matches
  - Use location with "Best Match"
    - Sent from server in Network in UE-assisted case

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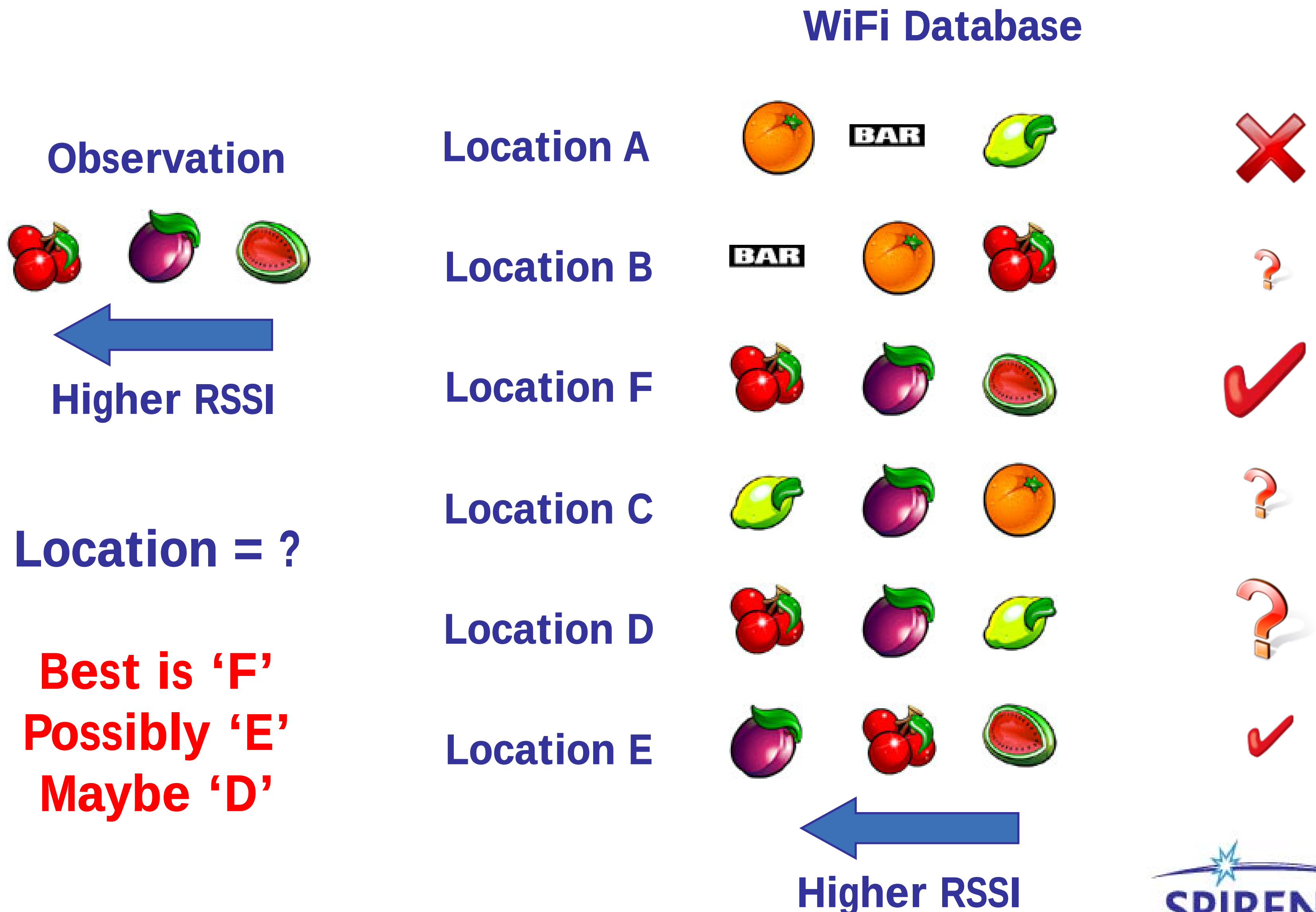
Fingerprinting Uses "Best Match" Principle



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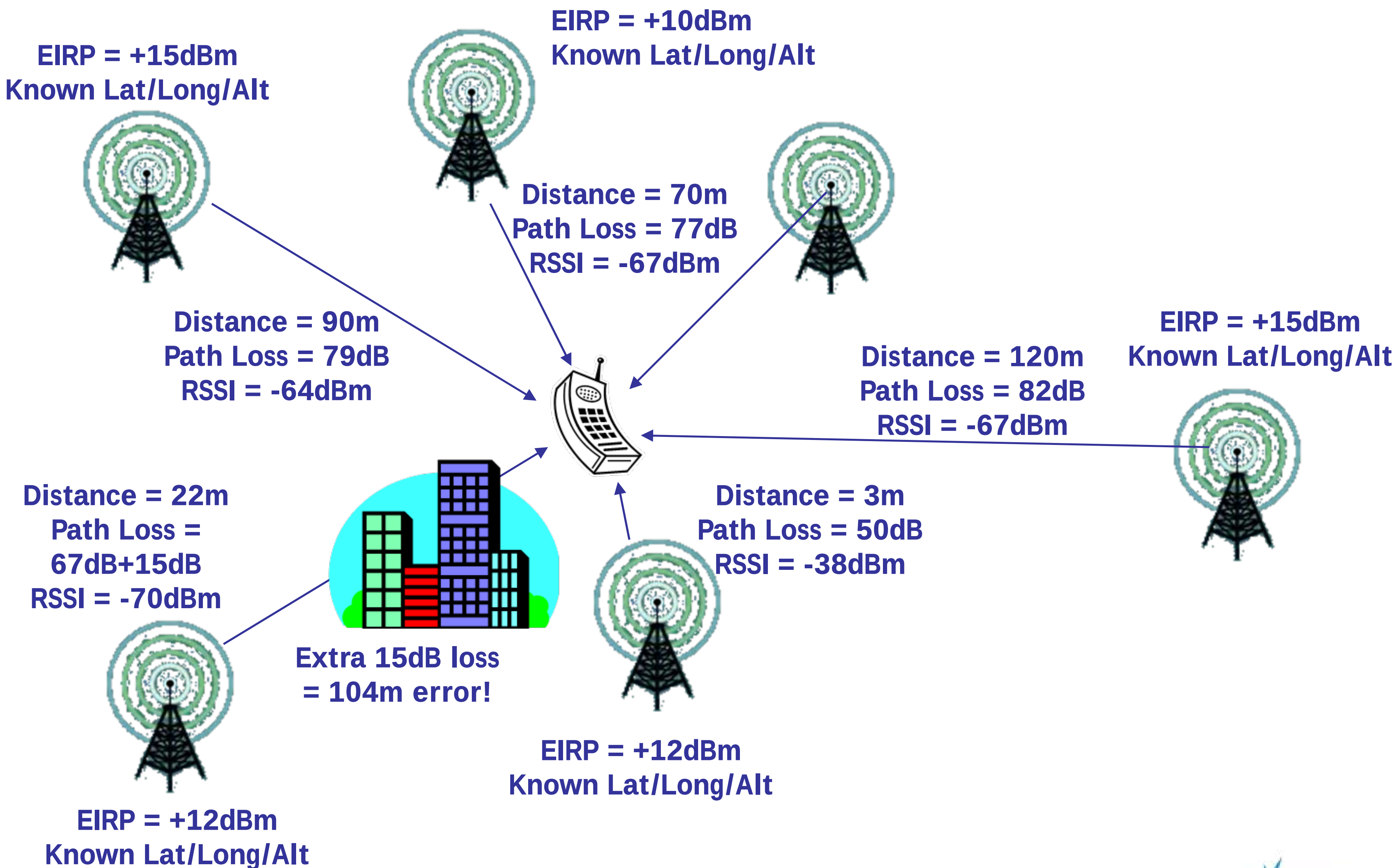
Trilateration



WiFi Positioning Test

- Existing solutions are not regulated
- There are few, if any, guarantees regarding accuracy and availability
- As a result, the need for formal testing has not yet been recognised
- However, as deployment grows, the need for regulation, driven by carriers, is expected
  - Likely also E-911 and E-112 driven requirements

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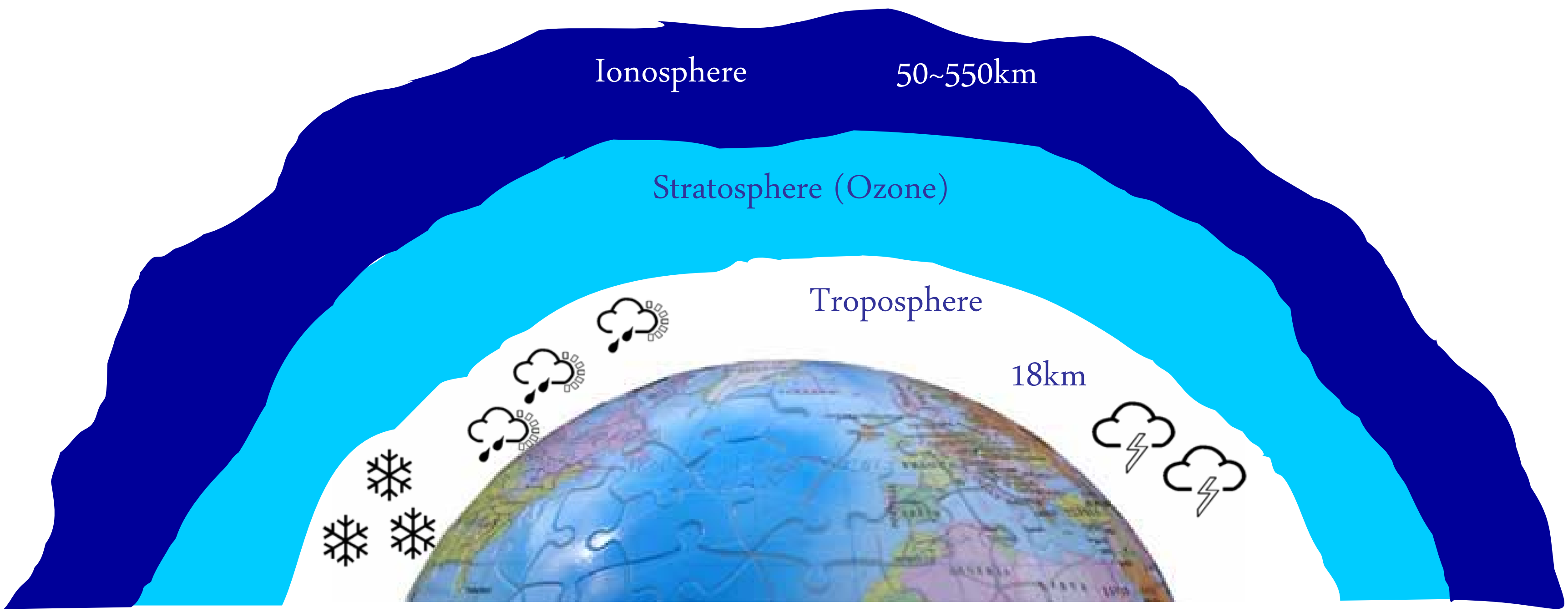
Ionospheric Scintillation

Atmospheric Layers

- The two layers of the atmosphere that effect GPS the most are the Troposphere and the Ionosphere



Typical GNSS Error Budget Composition

	Typical error (per satellites)	
	Standard GPS	DGPS
Satellite clocks	1.5m	0m
Orbit errors	2.5m	0m
Ionosphere	5m	0.4m
Troposphere	0.5m	0.2m
Receiver noise	0.3m	0.3m
Multipath	0.6m	0.6m

Source: www.trimble.com/gps/howgps-error2.shtml#3

Ionospheric Scintillation: Background

- Massive ejections of plasma occur creating ‘solar storms’
- Plasma moves as it is deflected by the ionosphere
- Greatest danger to satellite signals is at tropical latitudes, where ionospheric storms typically form after sunset & last for several hours
  - During the day, solar heating causes the ionosphere to rise near the equator and then fall under its own weight down magnetic field lines to form two bands of enhanced density on either side of the geomagnetic equator
  - At high latitudes, the threat to GPS comes during magnetic storms in which blobs of ionosphere from the dayside are swept over the polar cap onto the night-side
  - During the last solar maximum, magnetic storms were observed to fatten the ionosphere over the dayside United States and then carry blobs of it over the North Pole and polar cap into Europe

Scintillation map

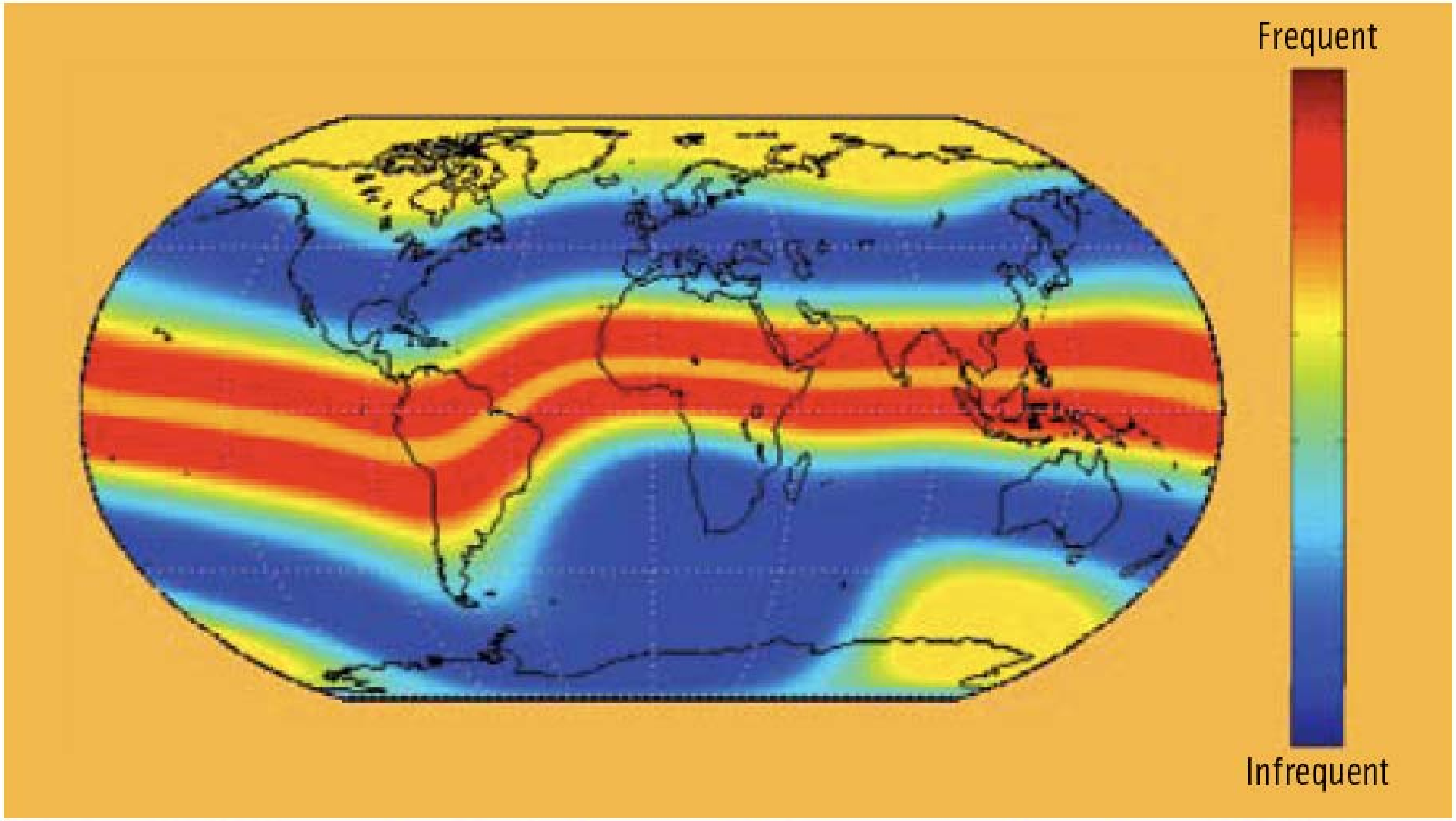


FIGURE 1 Scintillation map showing the frequency of disturbances at solar maximum. Scintillation is most intense and most frequent in two bands surrounding the magnetic equator, up to 100 days per year. At poleward latitudes, it is less frequent and it is least frequent at mid-latitude, a few to ten days per year.

http://www.insidegnss.com/node/1579

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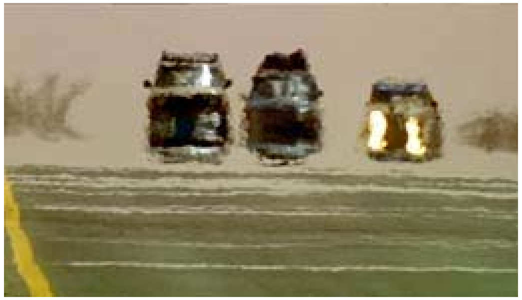
Ionospheric Scintillation: Background

- Scintillation affects GNSS signals in 2 ways
  - Refraction
  - Diffraction
- Refraction
  - If the TEC increases, the group velocity slows down and the phase velocity speeds up to keep their product a constant
    - The product of the group velocity and phase velocity of the GPS signals is equal to the speed of light squared
  - A slower group velocity produces ranging errors while a faster phase velocity causes unexpected phase shifts
  - If the phase shifts are rapid enough, they can challenge the tracking loops in GPS receivers' phase lock loops

Ionospheric Scintillation



- Diffraction
  - "Ionospheric Multipath"
    - When ionospheric irregularities form at scale lengths of about 400 meters, they begin to scatter GPS signals
    - The GPS signals on each path will add in a phase-wise sense, causing fluctuations in the signal amplitude and phase
  - You can see this effect with light, when viewing sunlight reflecting from glass through a heat haze
  - Both refractive and diffractive effects are called scintillation
  - Unfortunately, diffractive scintillation can seriously challenge GPS receivers
    - signal power fades exceeding 30 dB-Hz
    - fast phase variations

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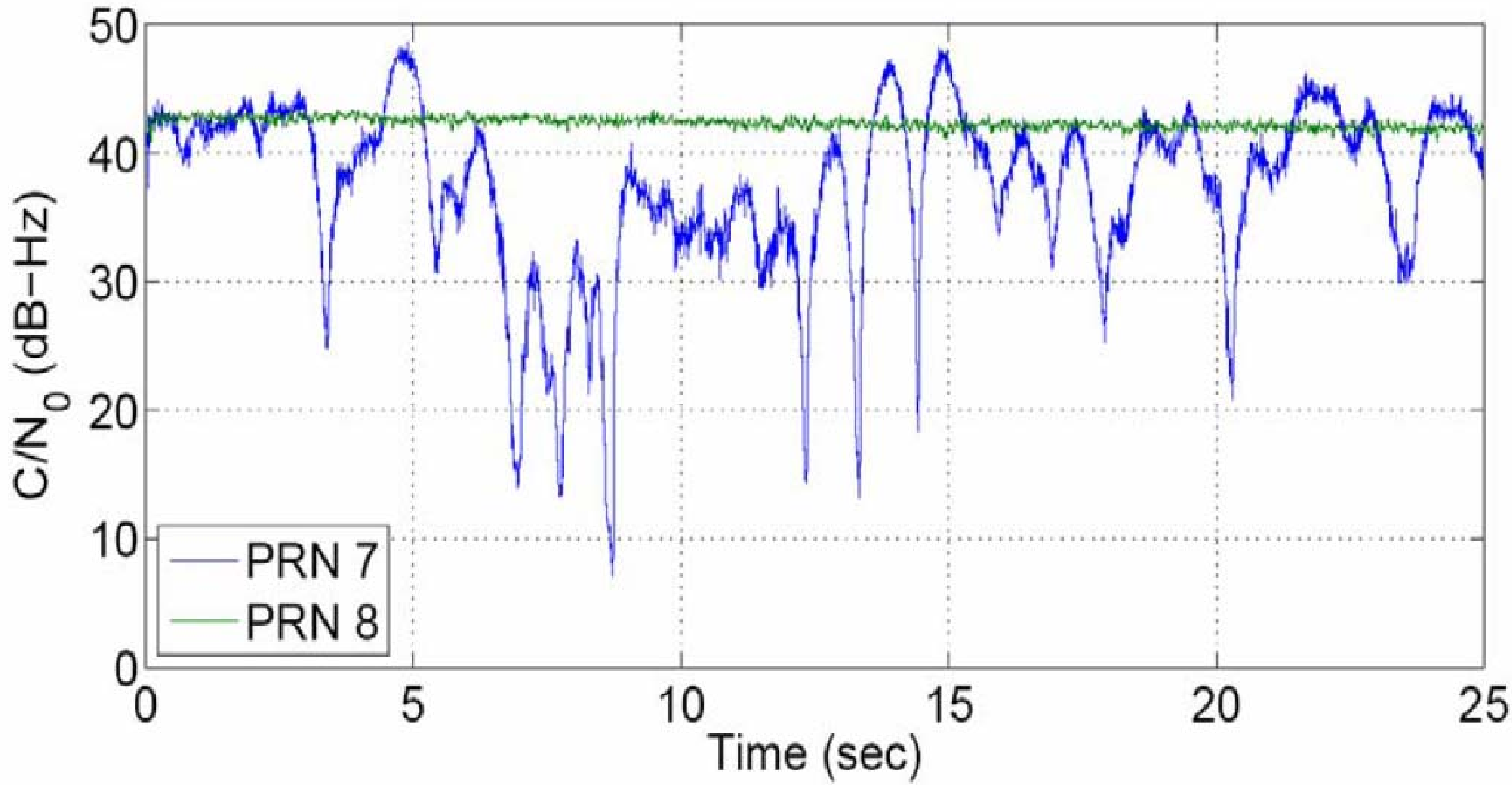
C/No comparison of 2 SVs, one scintillating, one not



http://gps.ece.cornell.edu/SpaceWeatherIntro_ed2_10-31-06_ed.pdf

2013 maximum

- Sun-spot count predicted to be approximately half that of previous event
  - BUT – the most intense plasma-ejecting solar flares often occur during below-average spot cycles
  - Solar flares are irregular , making prediction difficult

Effects on a receiver

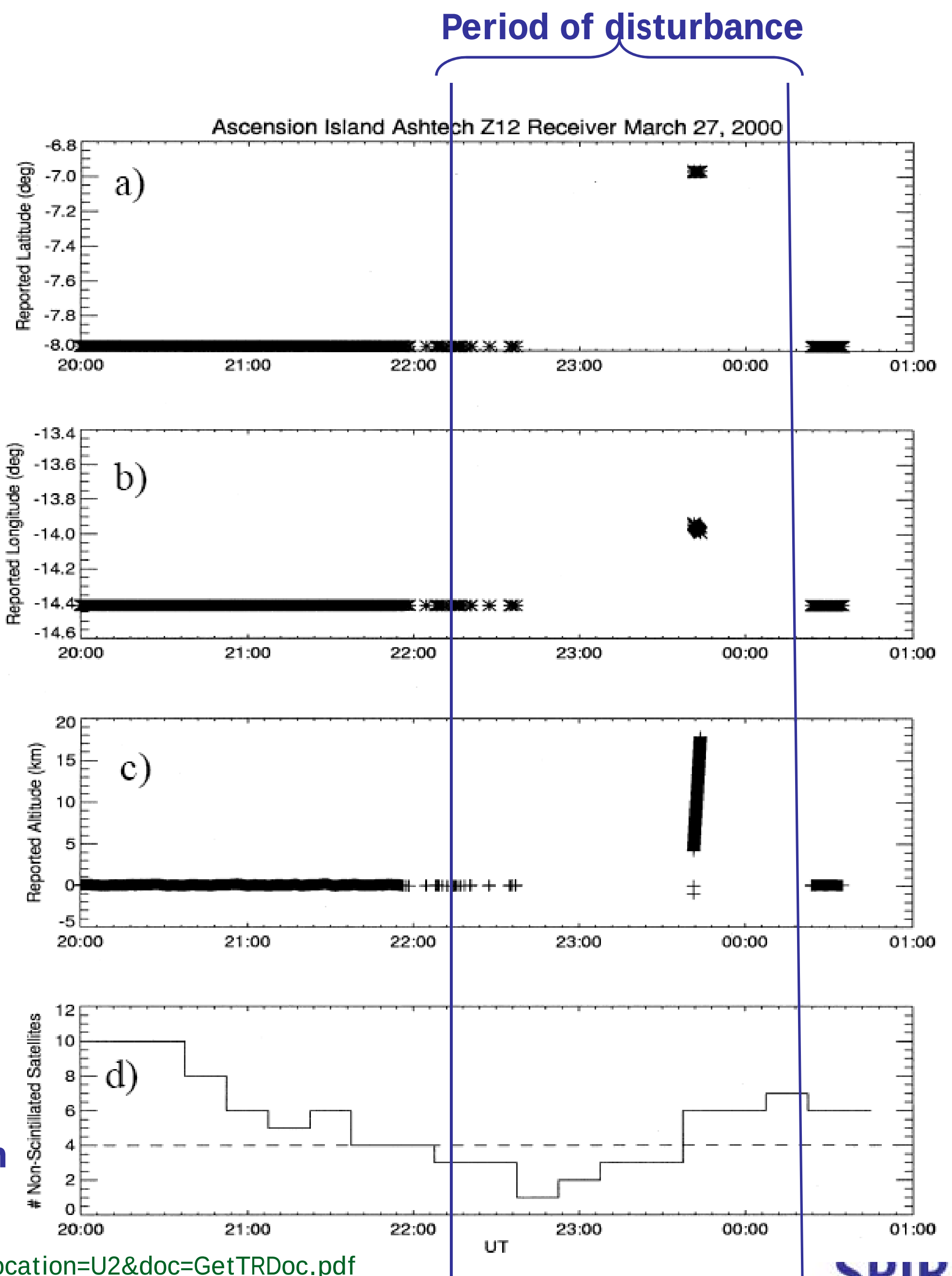
Ashtech Z12 on Ascension Island March 2000

Latitude

Longitude

Height

No. of SV's NOT affected by scintillation



http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA444409&Location=U2&doc=GetTRDoc.pdf

Summary

- Multi-GNSS with MEMS and Wi-Fi Positioning is becoming the ubiquitous solution for demanding consumer LBS
- More work is needed to characterise the effects of the up-coming solar maximum on GNSS receivers, particularly single frequency receivers at equatorial locations

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