African School on Space Science

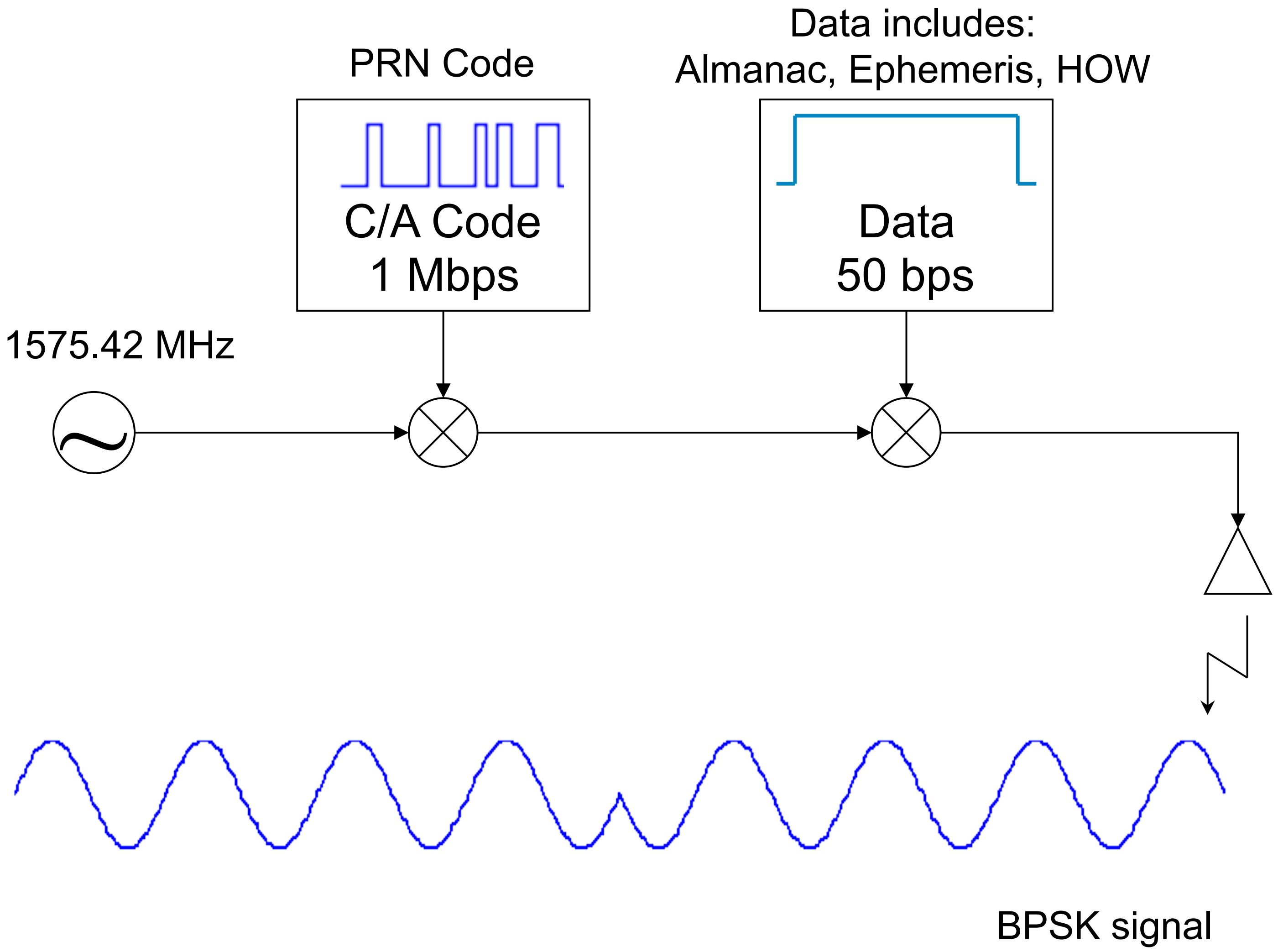
# Consumer GNSS Receiver Design
## & comparison with ionospheric scintillation studies

Reference:

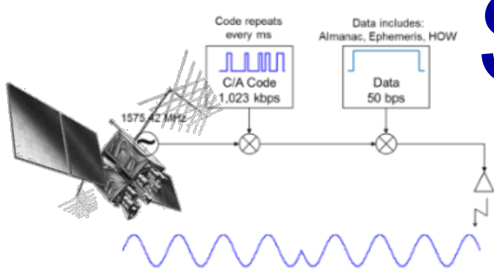
Chapters 2,3 of: "*A-GPS; Assisted GPS, GNSS & SBAS*", van Diggelen.

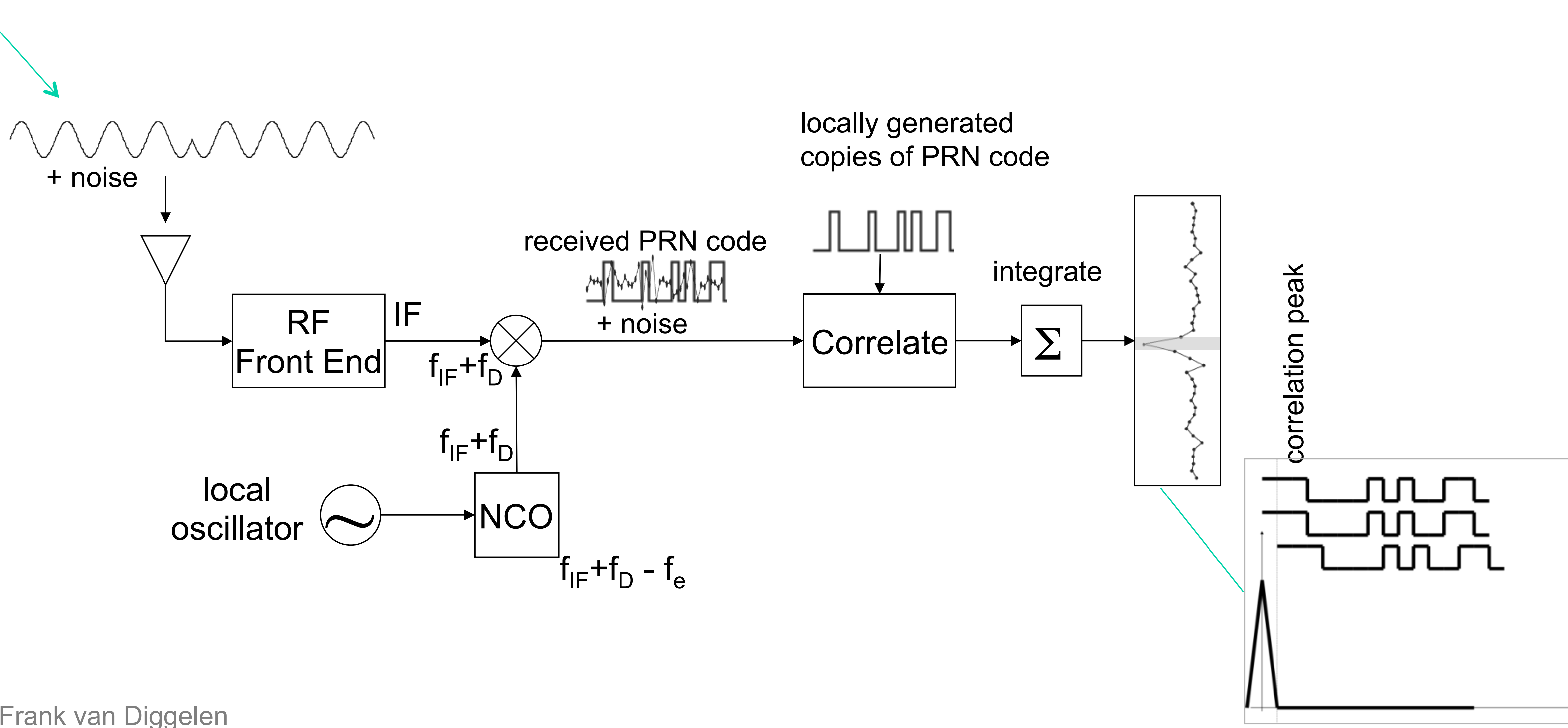
Chapters 11,12 of: "*Global Positioning System*", Misra & Enge

# GPS (Civilian) Signal at the Satellite

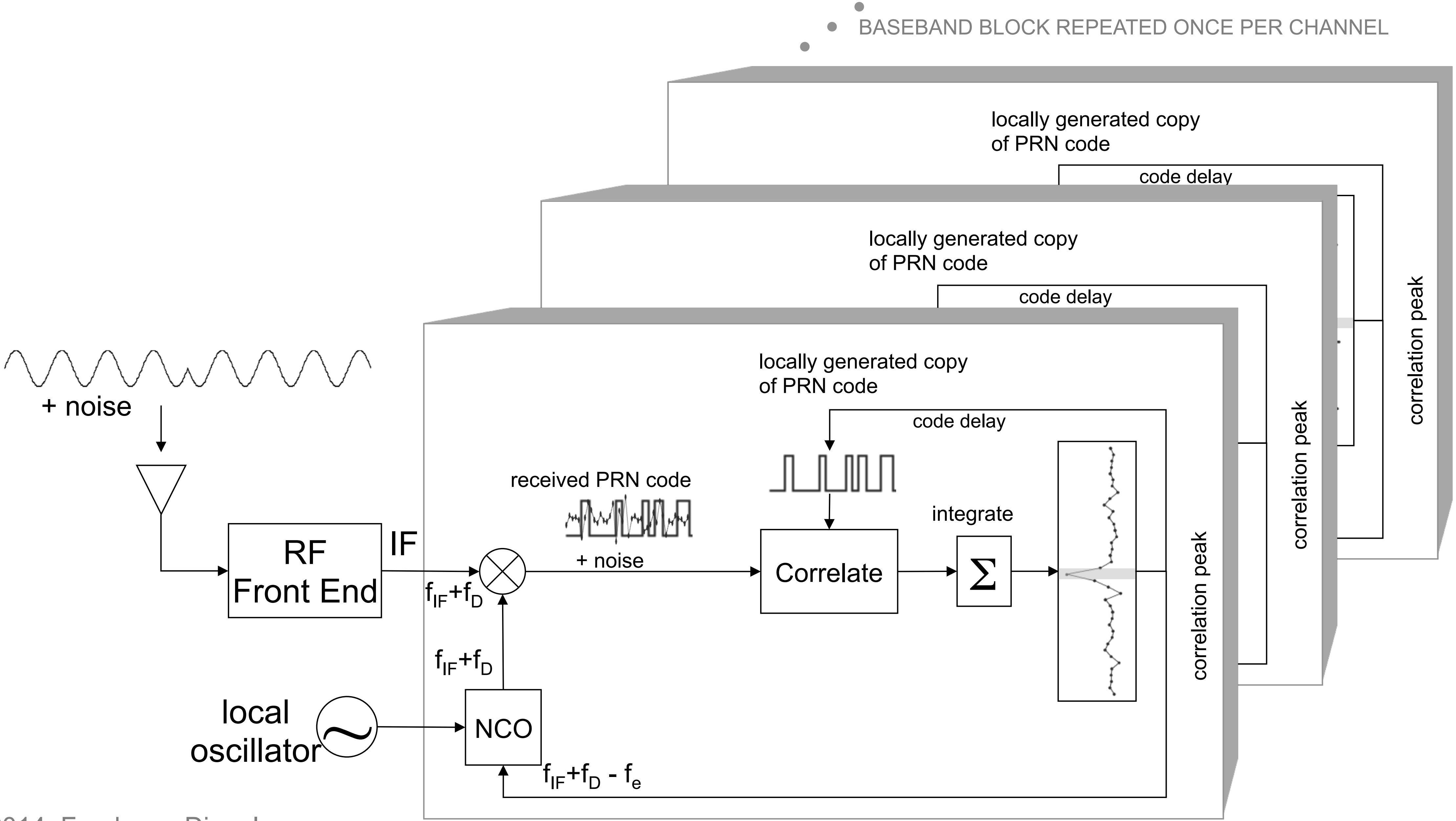


# Standard GPS receiver architecture

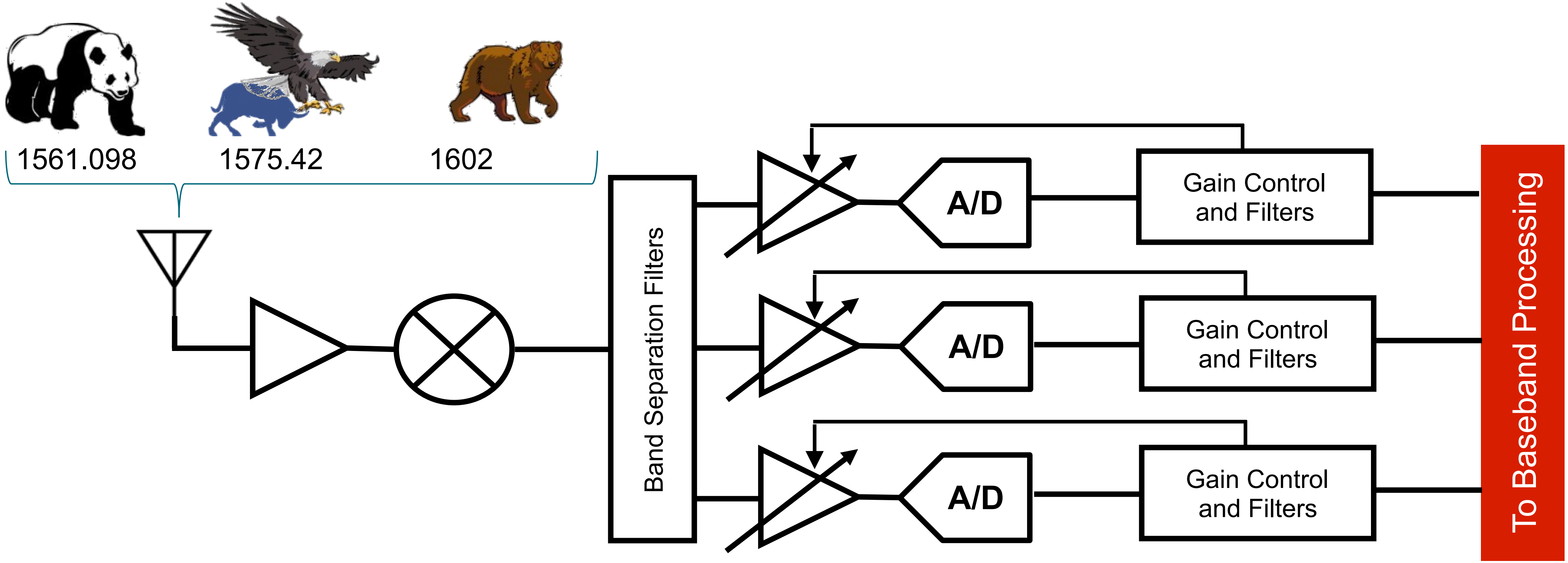


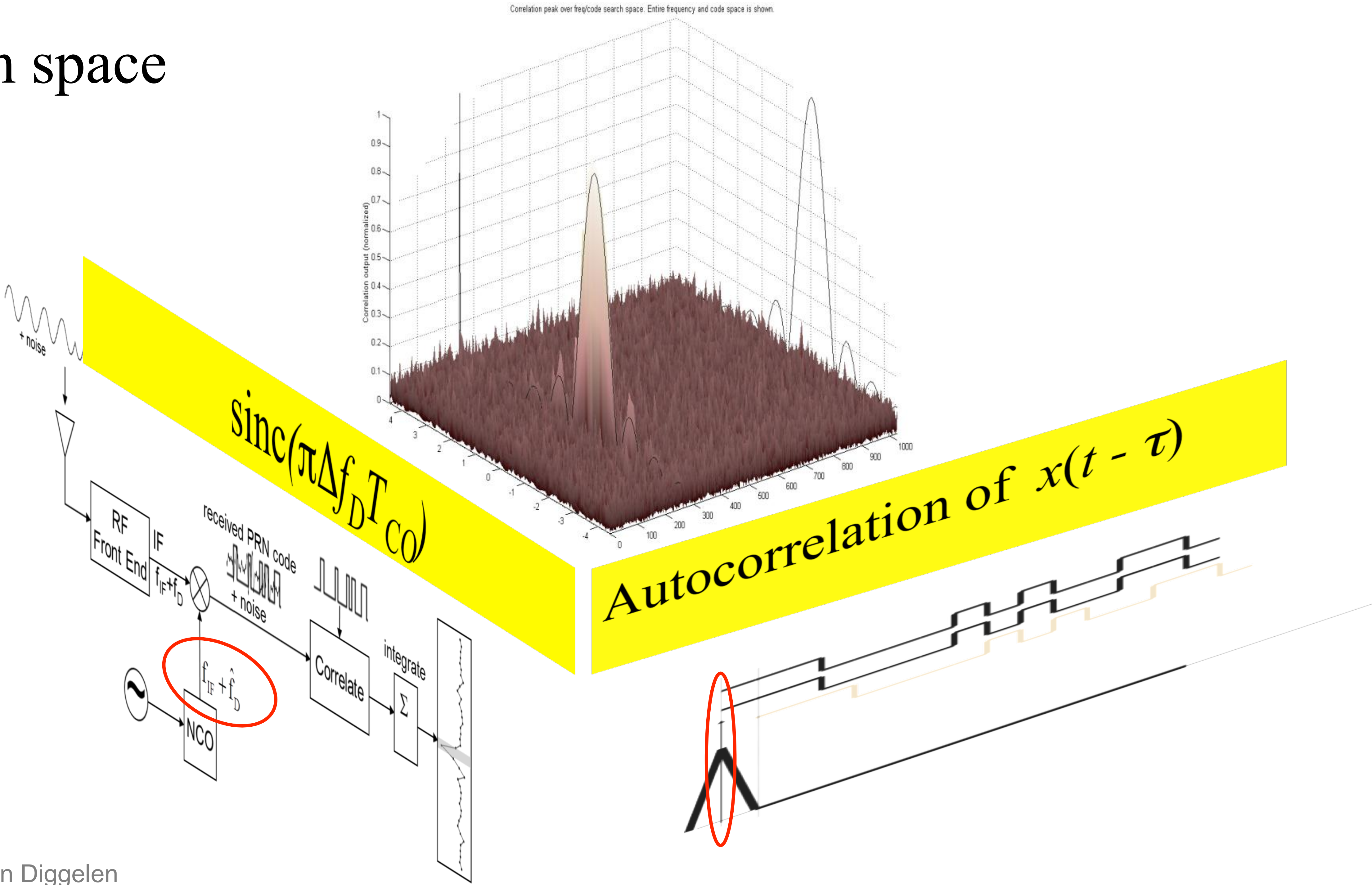
# Standard GPS receiver architecture



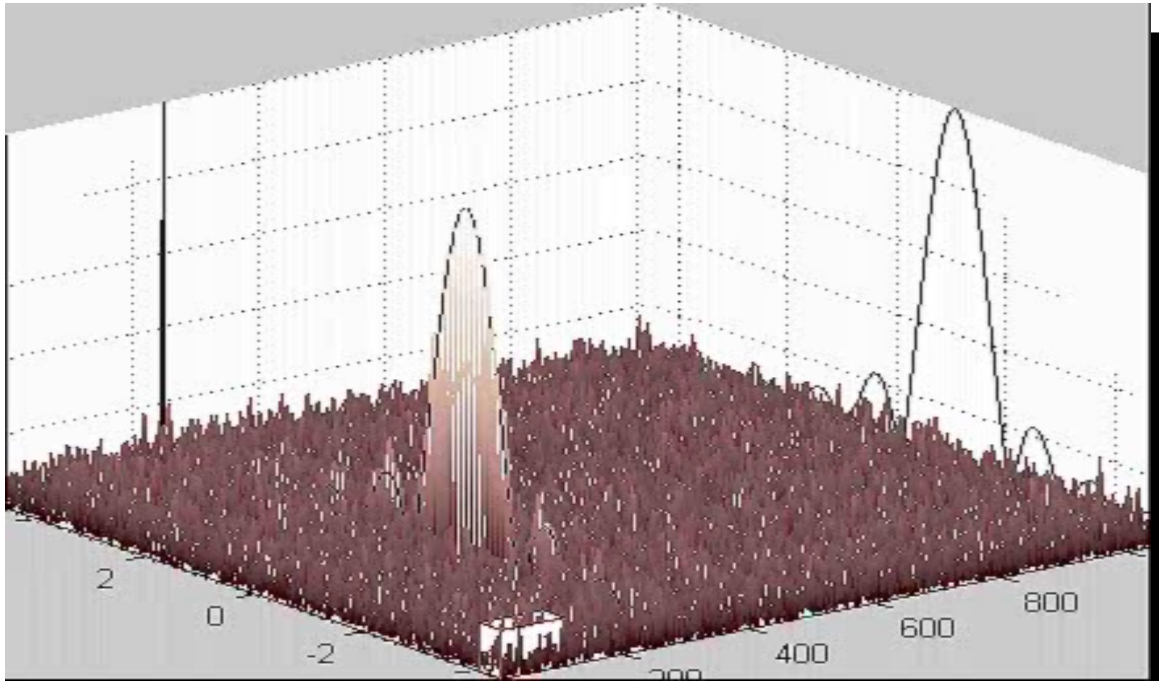
# Tri-band front end



# Search space

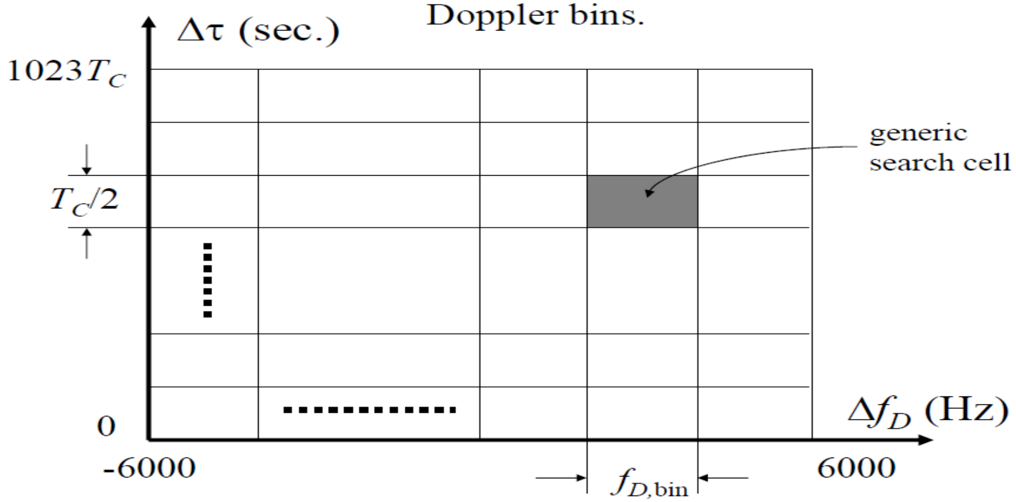


# Acquisition space review:

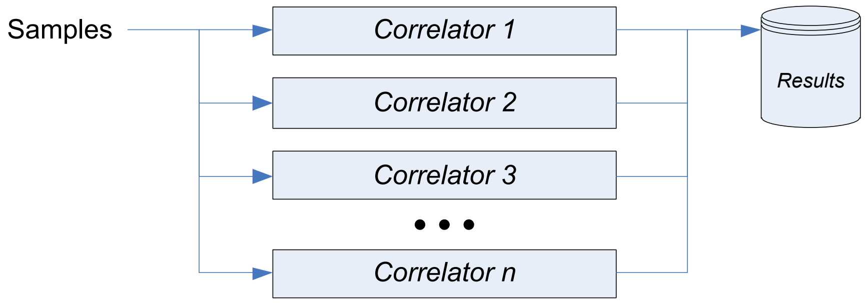



Real-time animation of standard GPS
search of freq/code space.
Click picture to play

Signal Search Area Covers Doppler Frequency ($\Delta f_D$) and Code Phase ($\Delta\tau$). The total number of cells in the search space, $M$, is equal to the number of code phase bins times the number of Doppler bins.

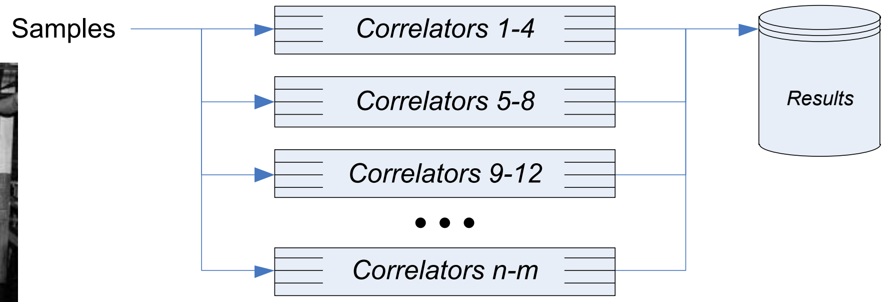


# Search Engine Evolution (1)

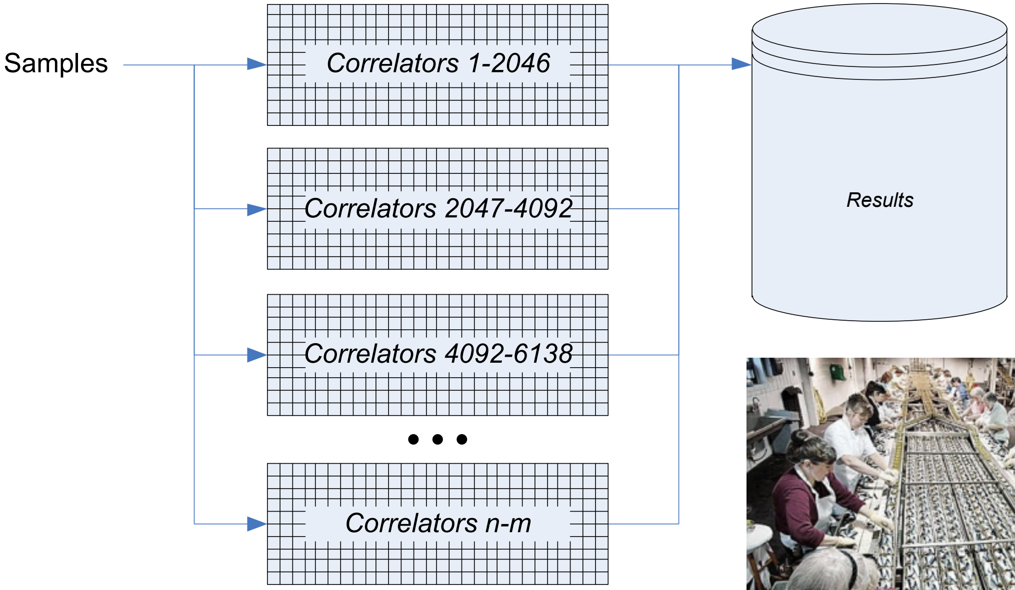



**Gen 1**

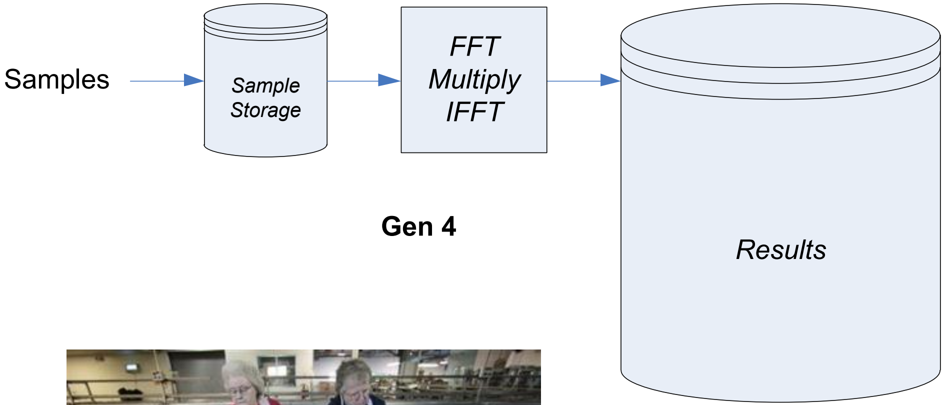
*Processing ca. 1993*




**Gen 2**




**Gen 3**



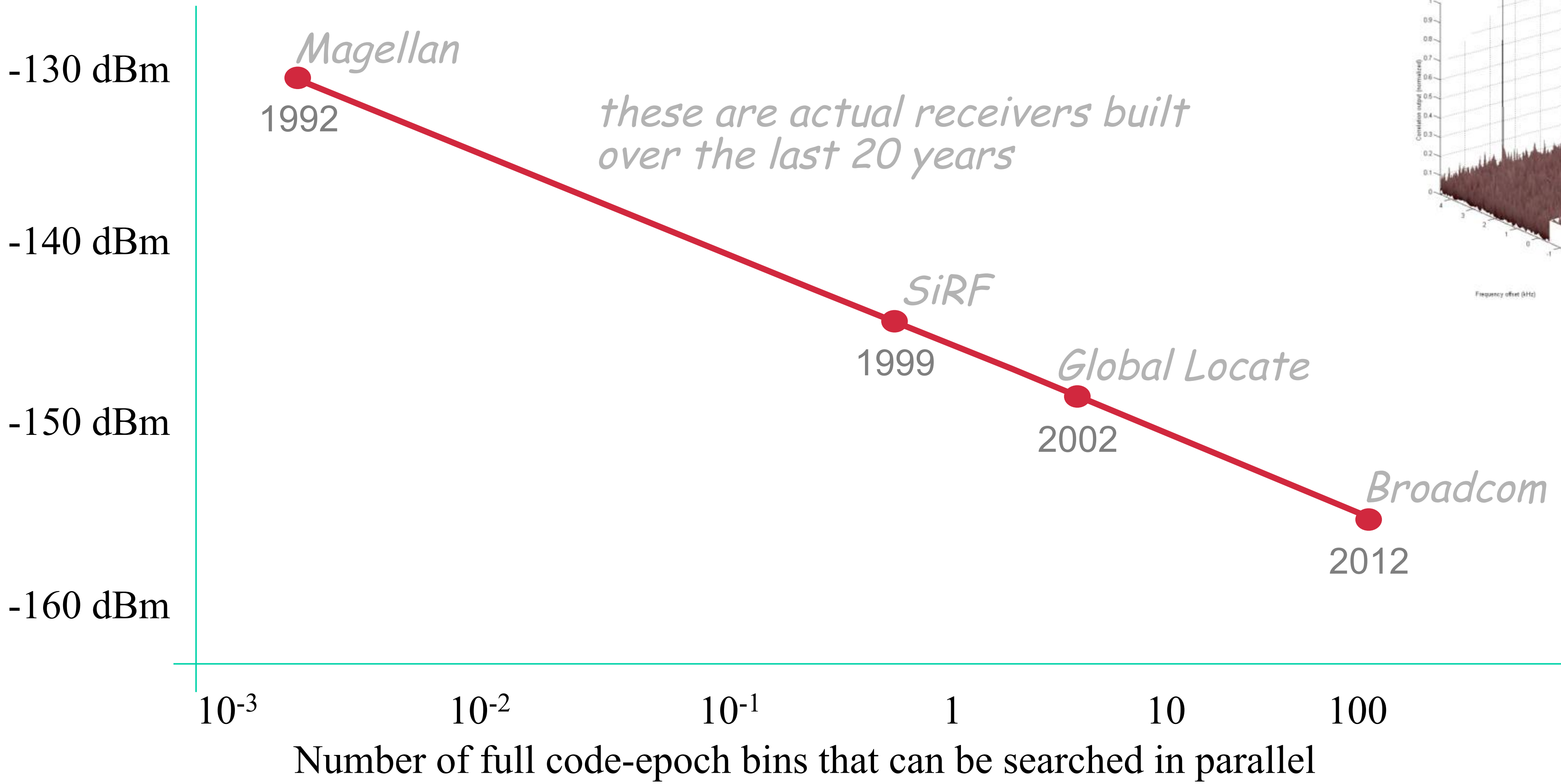

**Gen 4**

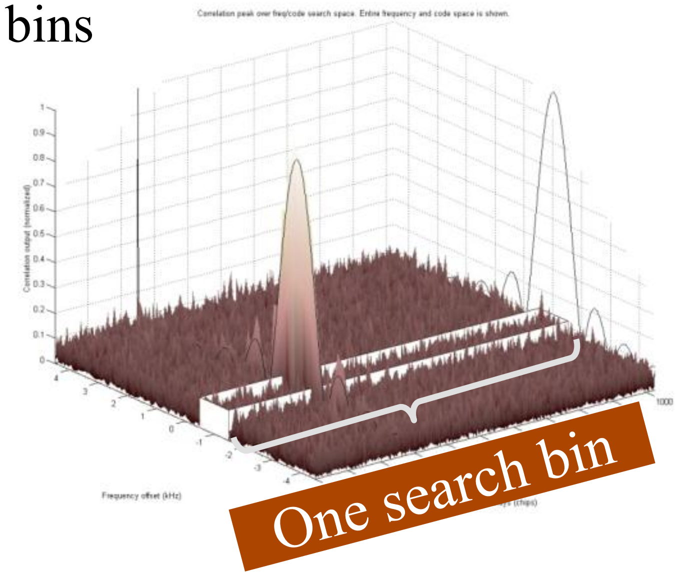
*Matched Filter Processing*

*FFT Processing*

# Search Engine Evolution (2)

Coarse-Time Acquisition Sensitivity (@ fixed TTFA of 10s) vs. number of code-epoch bins

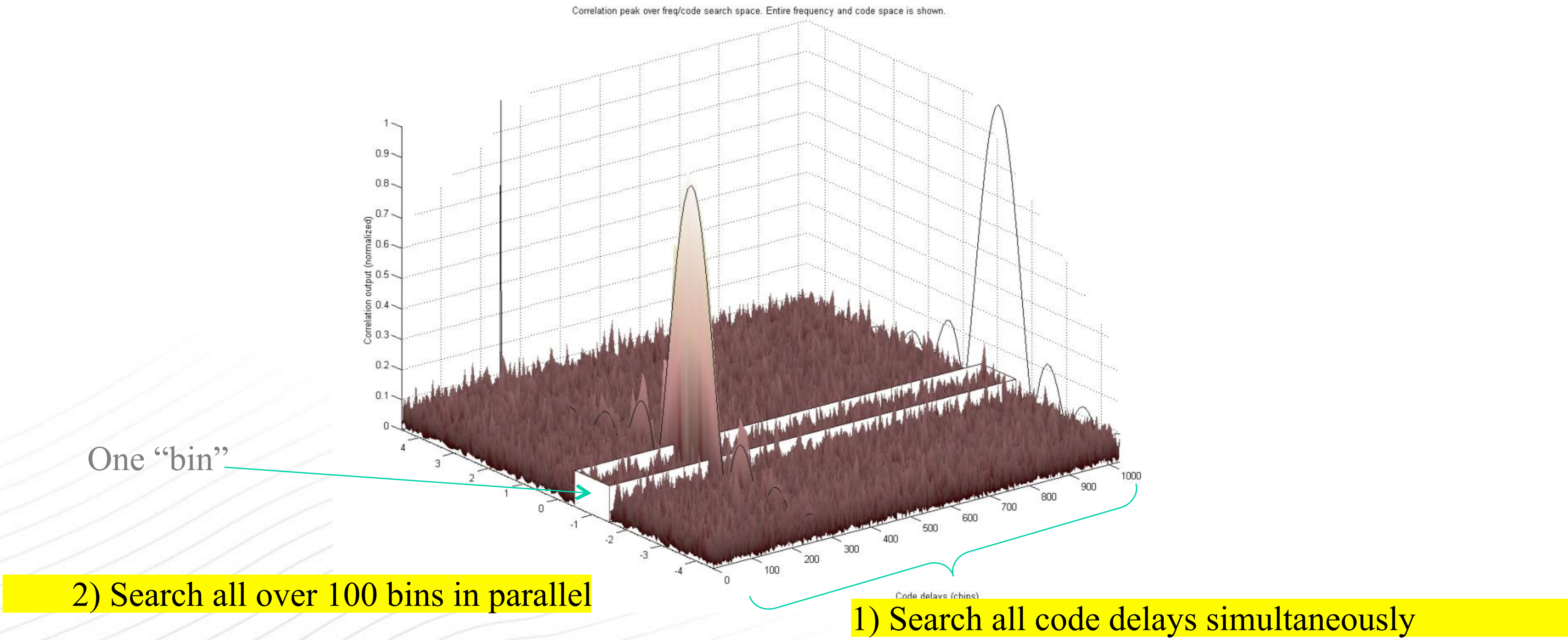


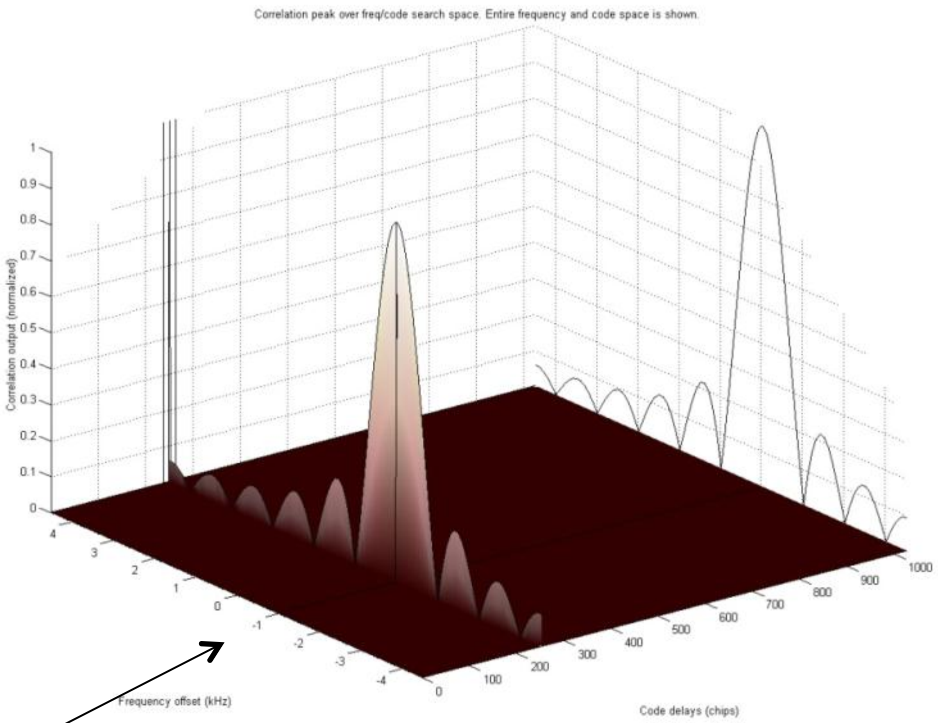



* With A-GPS assistance data: ± 100 ppb frequency, ± 2 s time, ± 3km position, ephemeris

# Broadcom GPS



# Contributors to frequency offset




8.4 kHz (satellite motion)

0.15 kHz / 100 km/h (receiver speed)

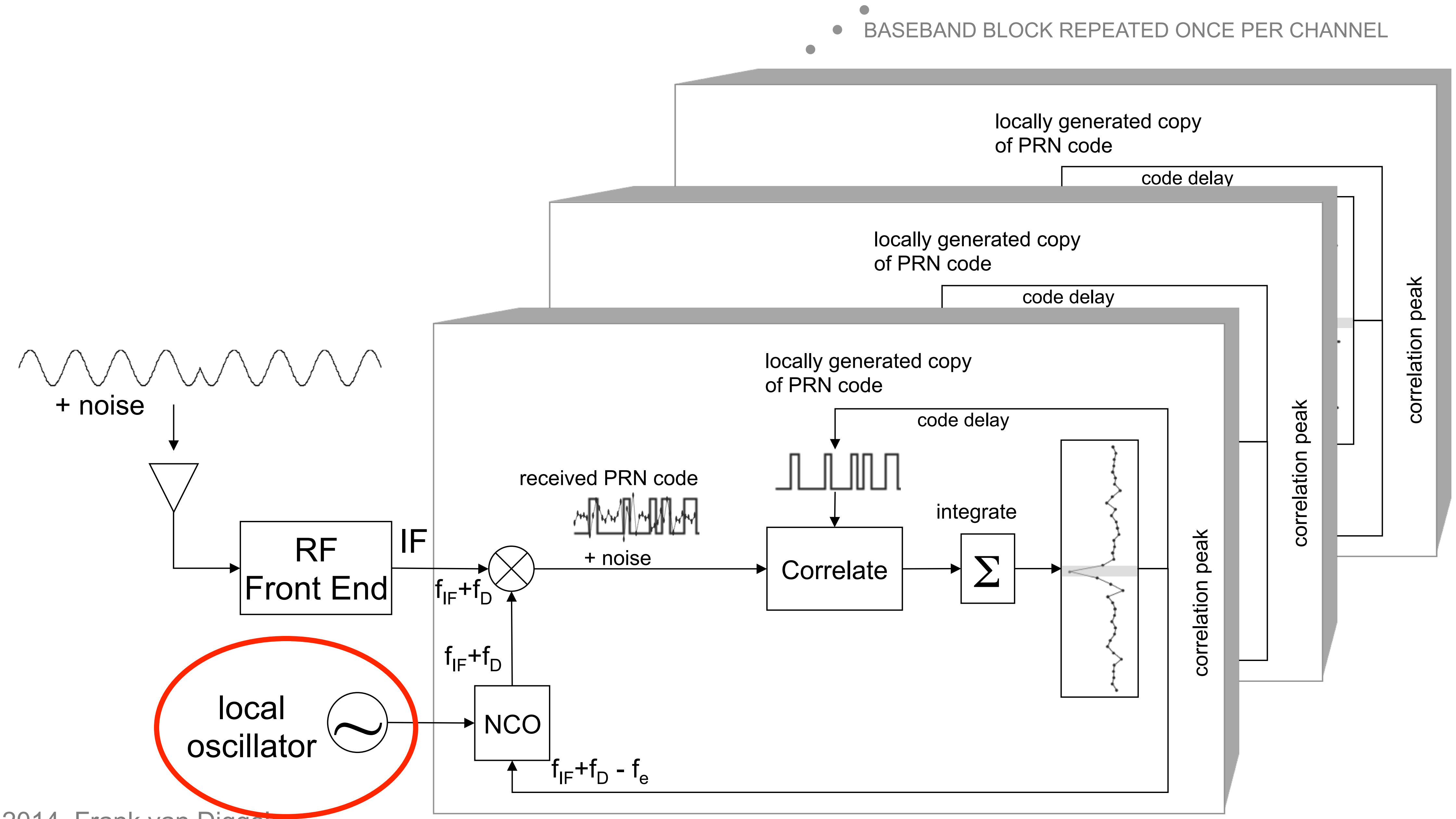
1.5 kHz/ppm (oscillator)

0.1 kHz / 100km (init. position)

0.0008 kHz / s (init. Time)

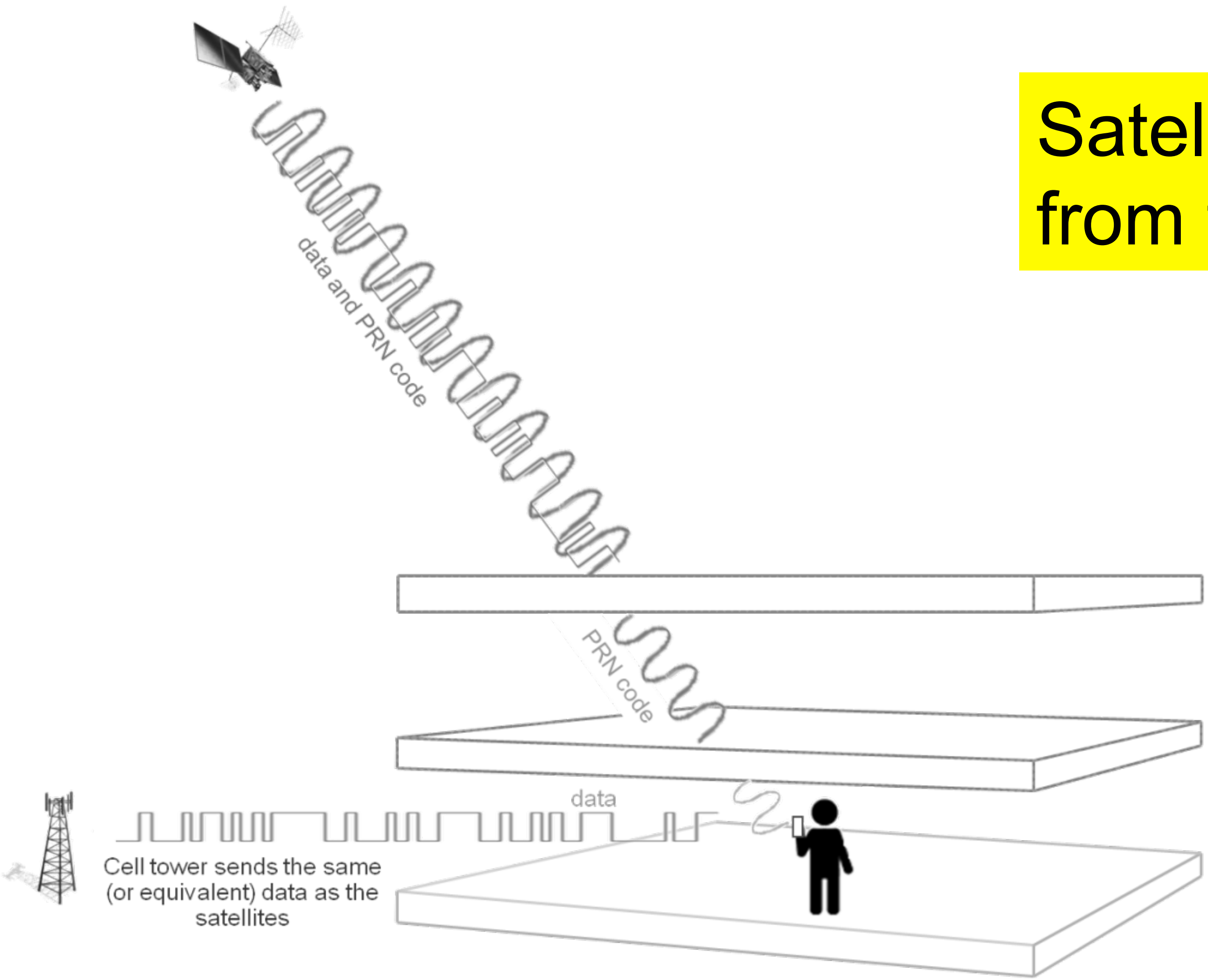
Dependence on oscillator stability
Does this mean the consumer market will lead to better oscillators?

# Reminder of receiver design



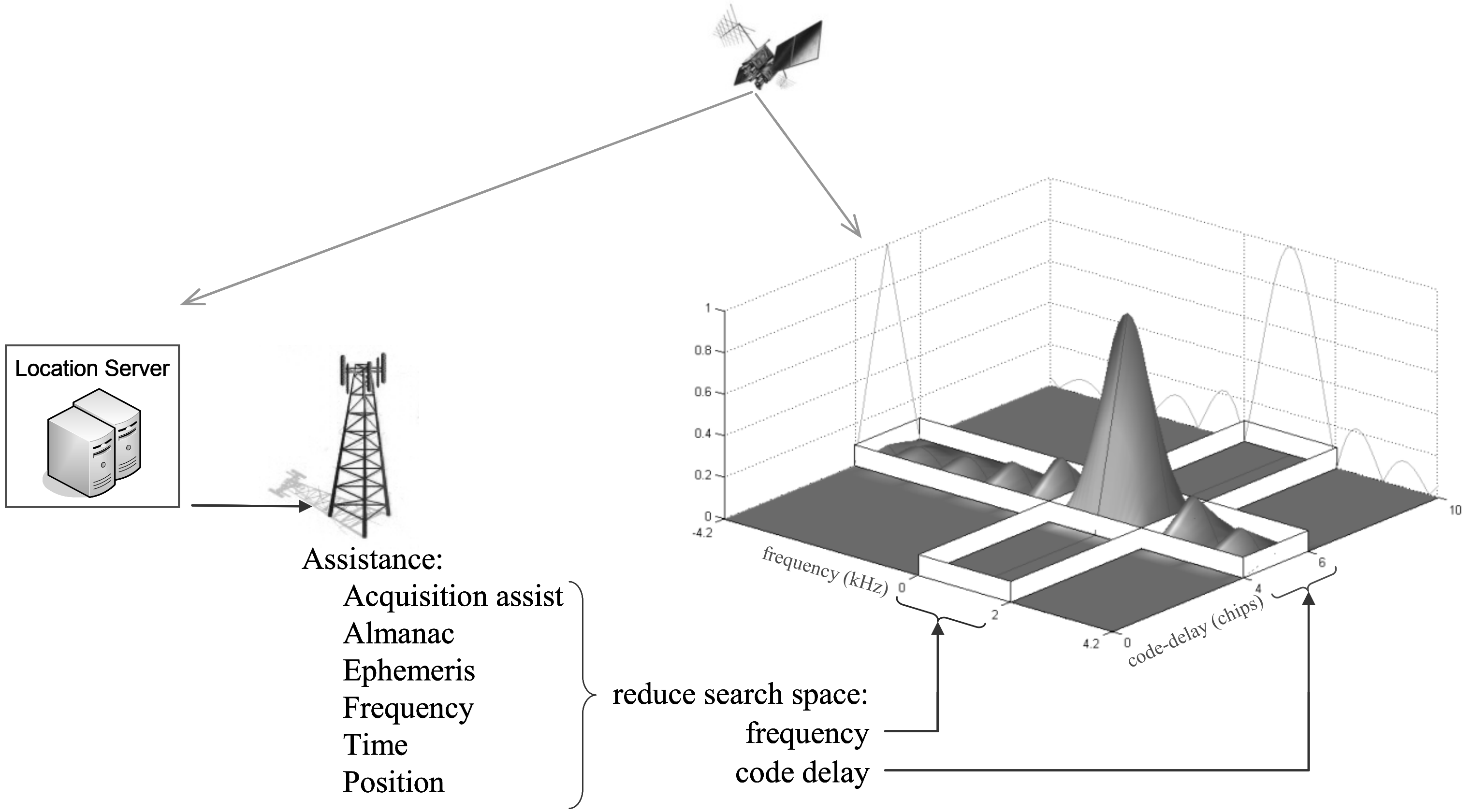
# Assisted GNSS (1)

Satellite nav data from the internet

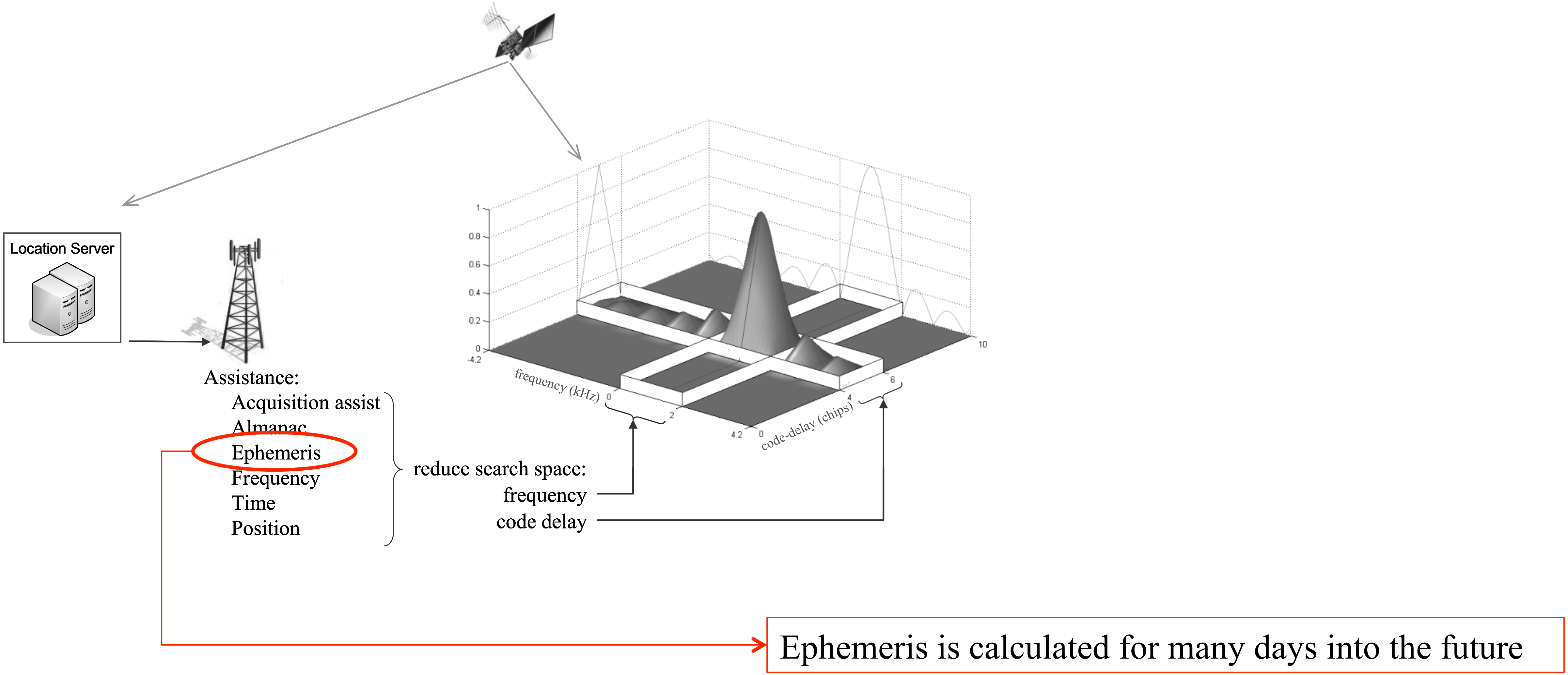


# Assisted GNSS (2)

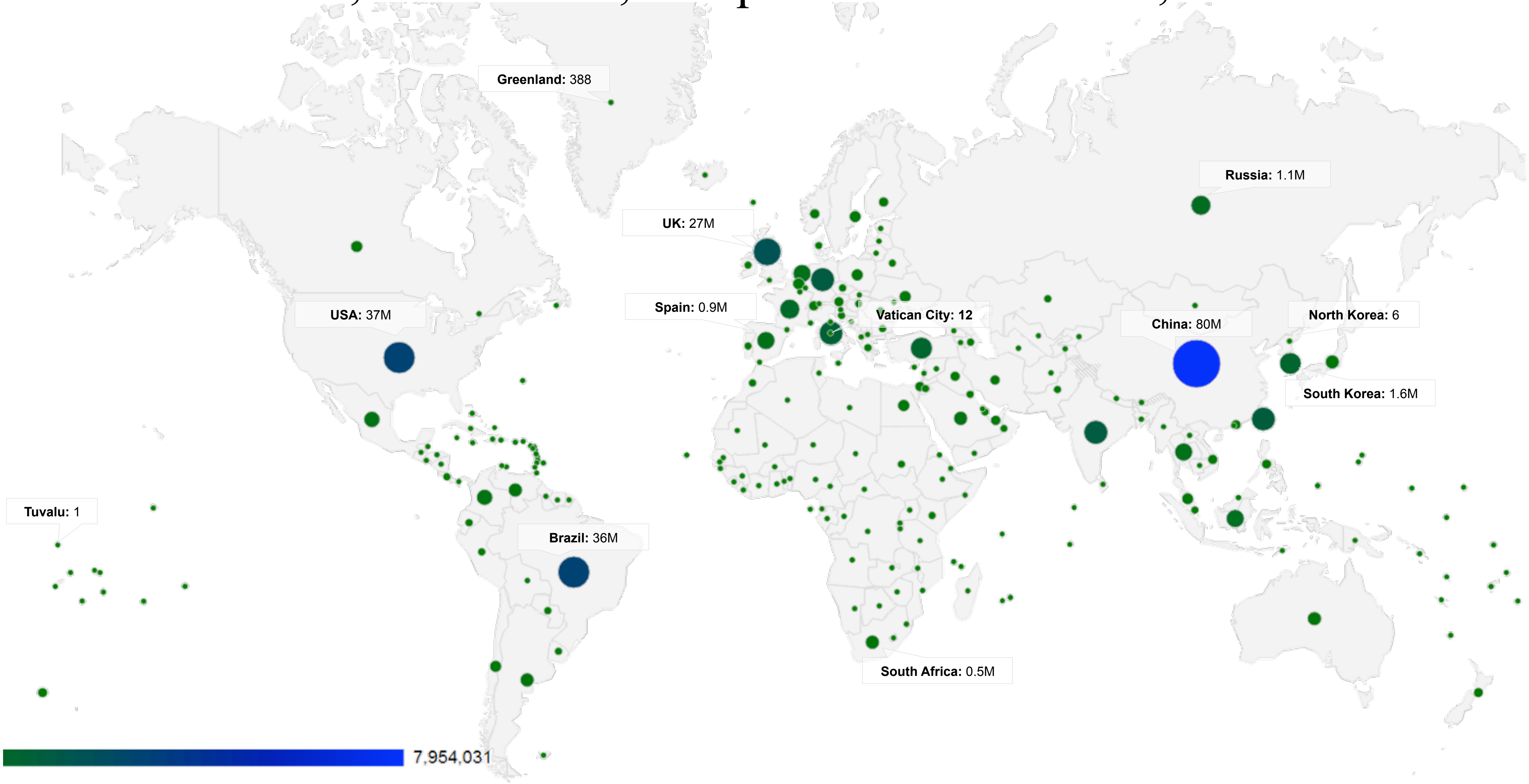
Reduced search space
⇒ quicker acquisition
⇒ higher sensitivity



# Long Term Orbits (LTO)
# (aka Extended Ephemeris)



# Broadcom, LTO Server, Unique Android Visitors, in 24 hours



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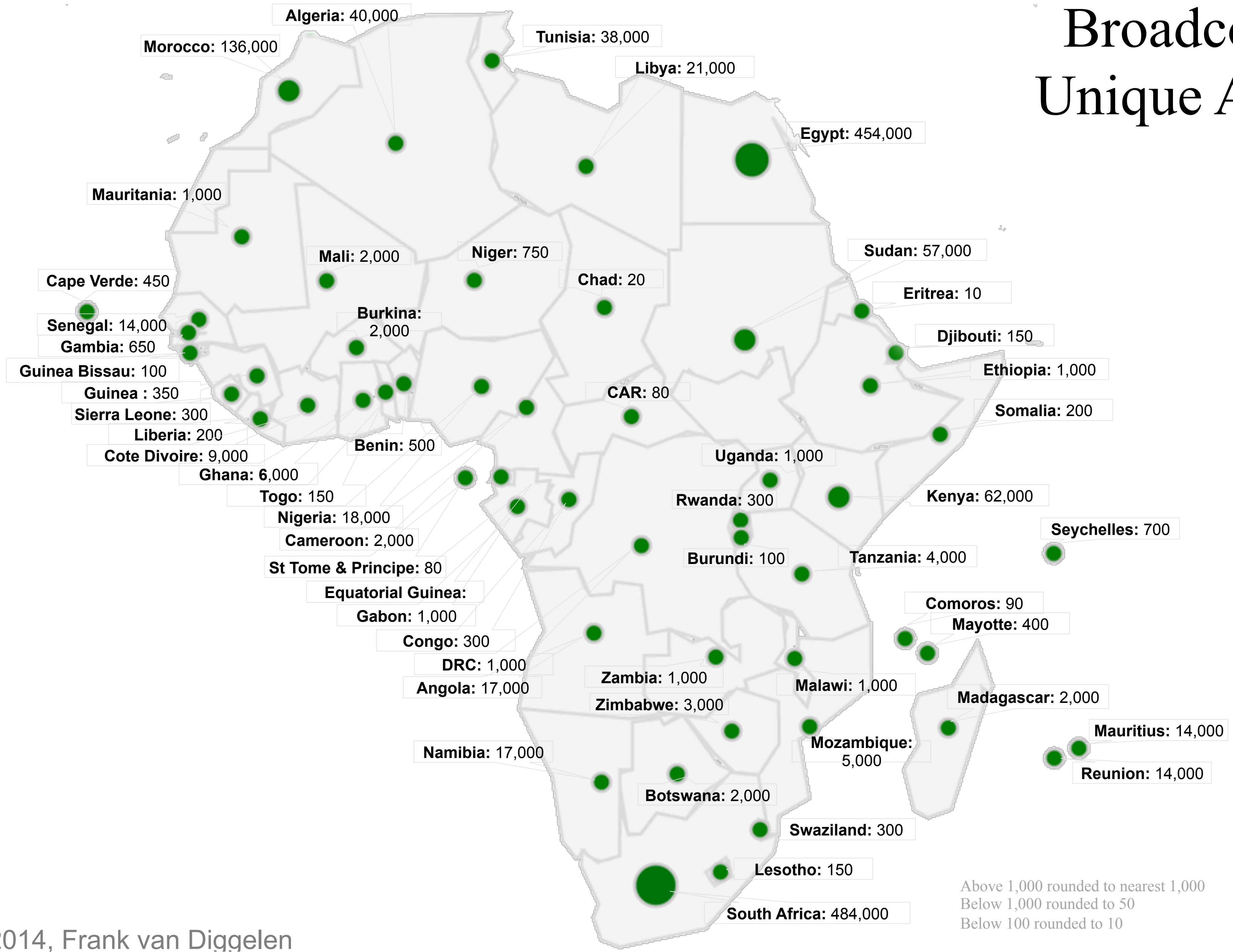
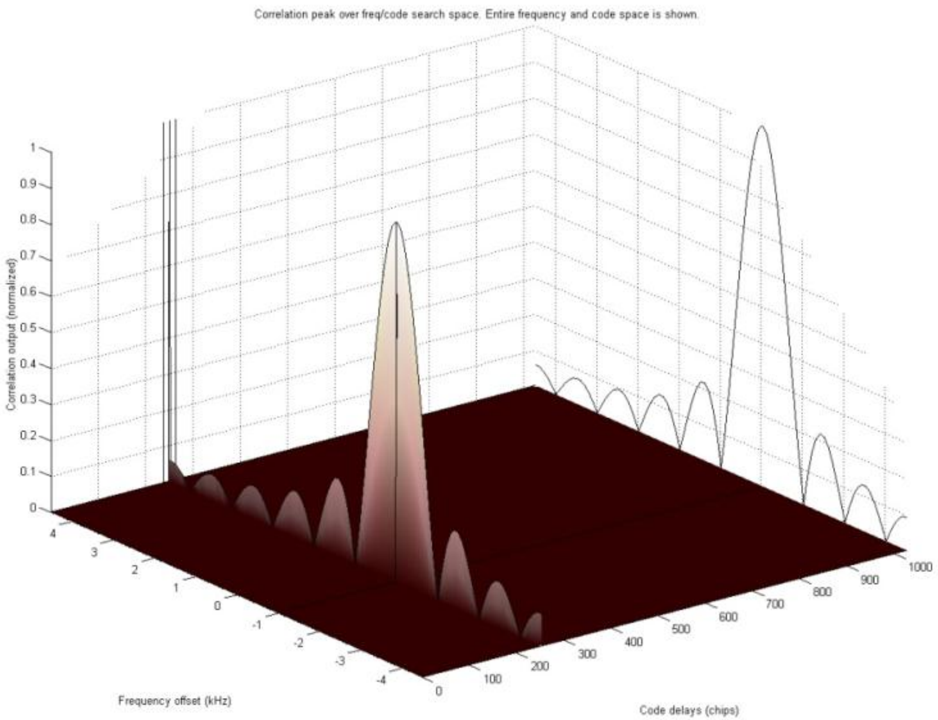



Above 1,000 rounded to nearest 1,000
Below 1,000 rounded to 50
Below 100 rounded to 10

# Back to search space with A-GNSS




~~8.4 kHz (satellite motion)~~

0.15 kHz / 100 km/h (receiver speed)

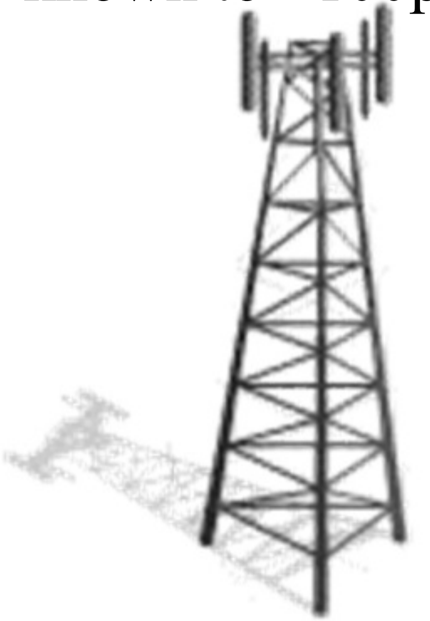
1.5 kHz/ppm (oscillator)

0.1 kHz / 100km (init. position)

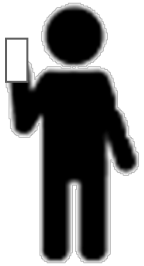
0.0008 kHz / s (init. Time)

# Frequency assistance

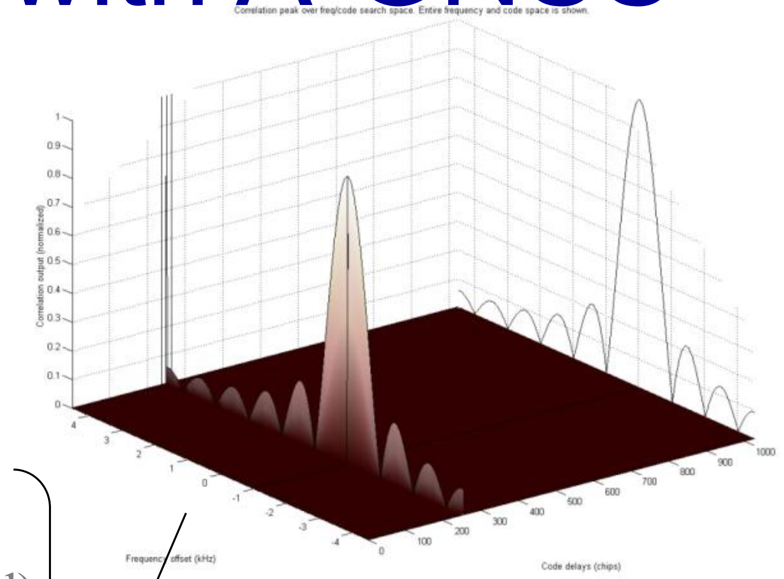
Cell towers have oscillators that are known to ±100ppb



A cell-phone communicating with a tower can calibrate its internal oscillator to ±100ppb



# Back to search space with A-GNSS




~~8.4 kHz (satellite motion)~~

0.15 kHz / 100 km/h (receiver speed)

± 0.15 kHz/100ppb — 1.5 kHz/ppm (oscillator)

0.1 kHz / 100km (init. position)

0.0008 kHz / s (init. Time)

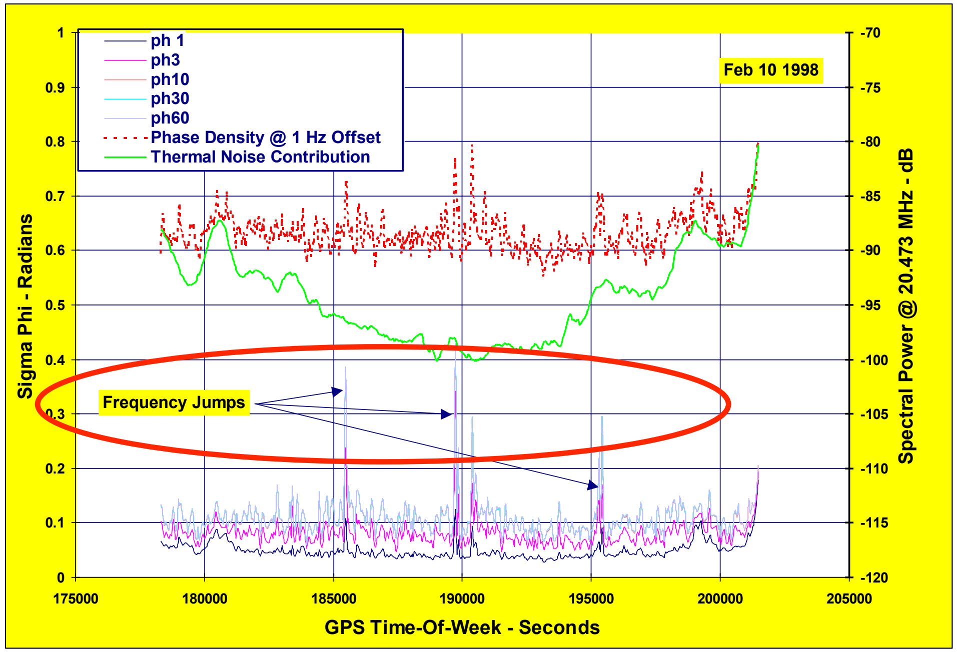
Result: remaining search space is a fraction of a kHz, easily within the capabilities of modern receivers. And so the trend is towards *worse* (= cheaper) oscillators in consumer products ☹.

# OSCILLATORS & IONO ...

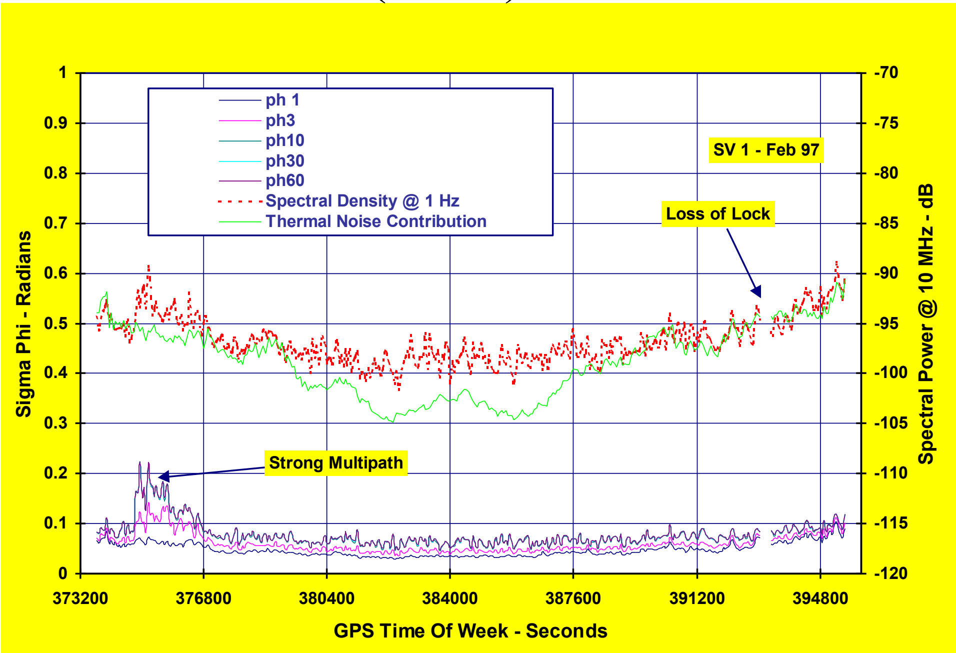
# Studying ionospheric scintillation

Measuring phase scintillation: must remove effects of receiver oscillator
Frequency jumps are not tolerable:

20 MHz OCXO (Bad)




10 MHz OCXO (Good)

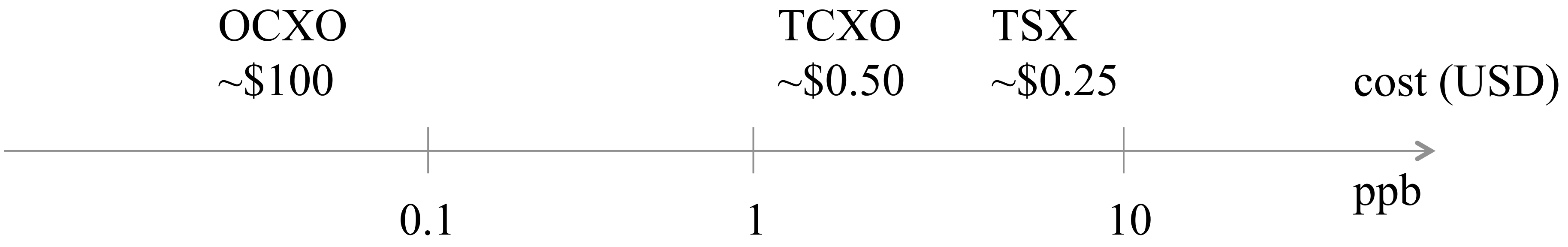



Conclusion: higher frequency OCXO showed jumps of the order of 1 rad/s in measured phase ≈ 0.1 ppb

“Crystal Oscillator Noise Effects on the Measurement of Ionospheric Phase Scintillation Using GPS”,
A.J. Van Dierendonck & Quyen Hua IEEE Frequency Control Symposium. May 1998

# Oscillator summary

Typical frequency jumps in different types of oscillators




Summary:

for consumer products to measure iono scintillation effect on phase you would need (at least) to change the crystal oscillator.

# Measuring scintillation using observed C/No

# MEASURING TEC …

# State of the art, and trends

- Current consumer GNSS is multi-frequency, but across different systems (therefore different satellite clocks)

- However, the trend is towards L1 and L5
- In the next decade you may see consumer products measuring multi GNSS systems on dual frequencies (L1, L5)

# Summary

- You've seen consumer GNSS designs and trends
  - half for your general knowledge
  - half relevant to your work
- Consumer products have some (small) overlap with GNSS for space science today
- And may be quite useful in years to come