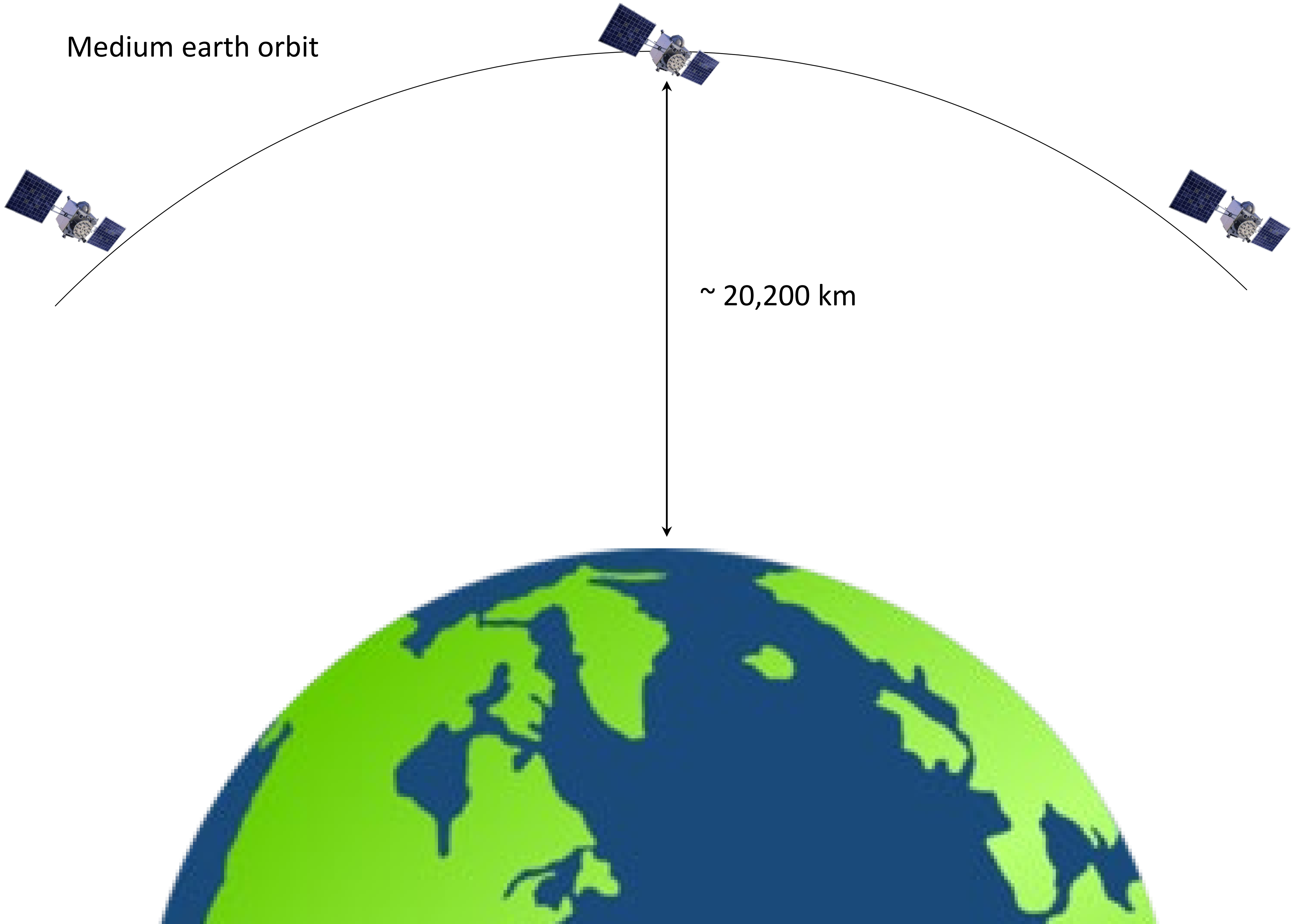
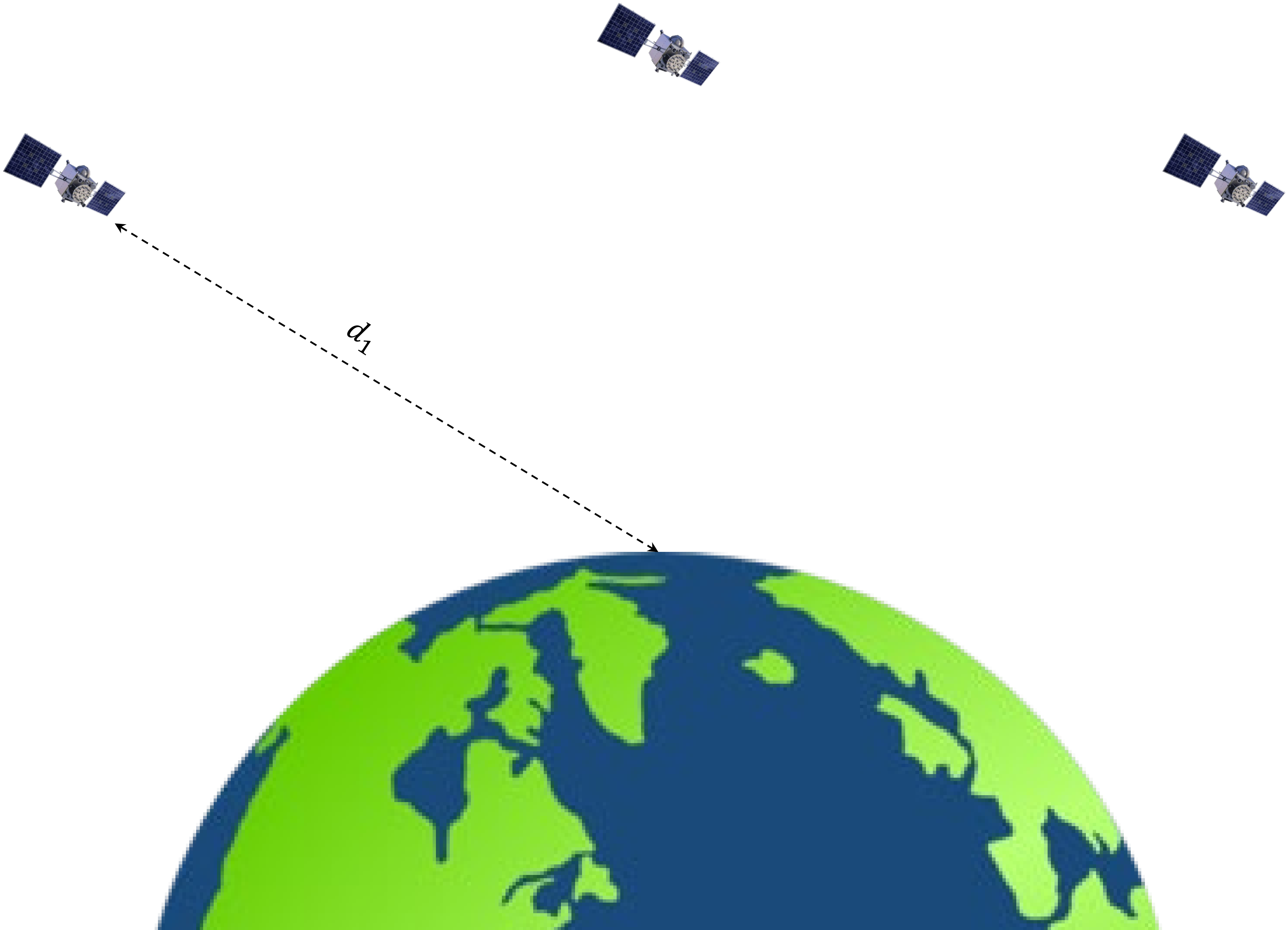
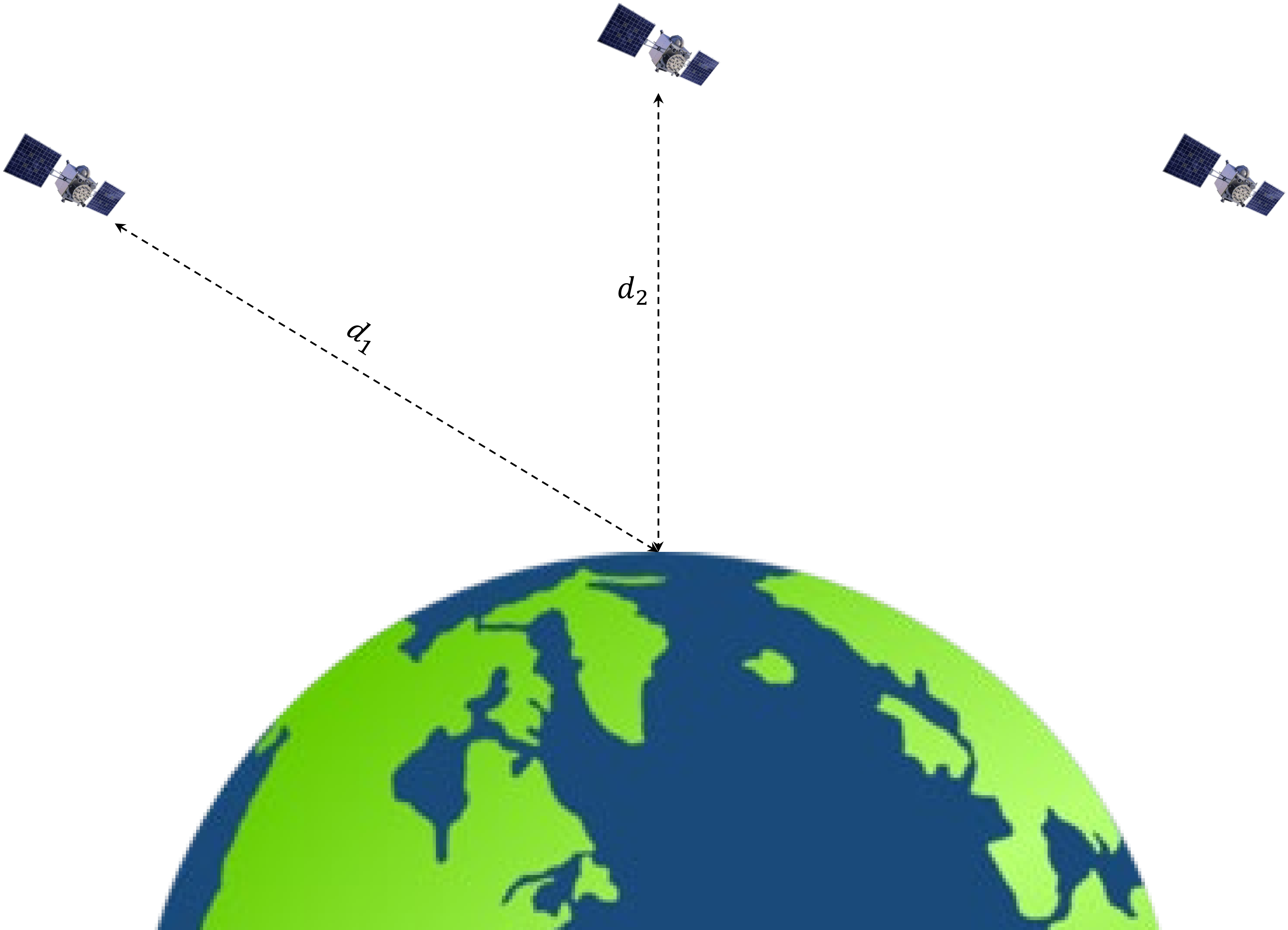
Detection and Processing of Bistatically Reflected GPS Signals From Low Earth Orbit for the Purpose of Ocean Remote Sensing

Presentation by Jack Rademacher

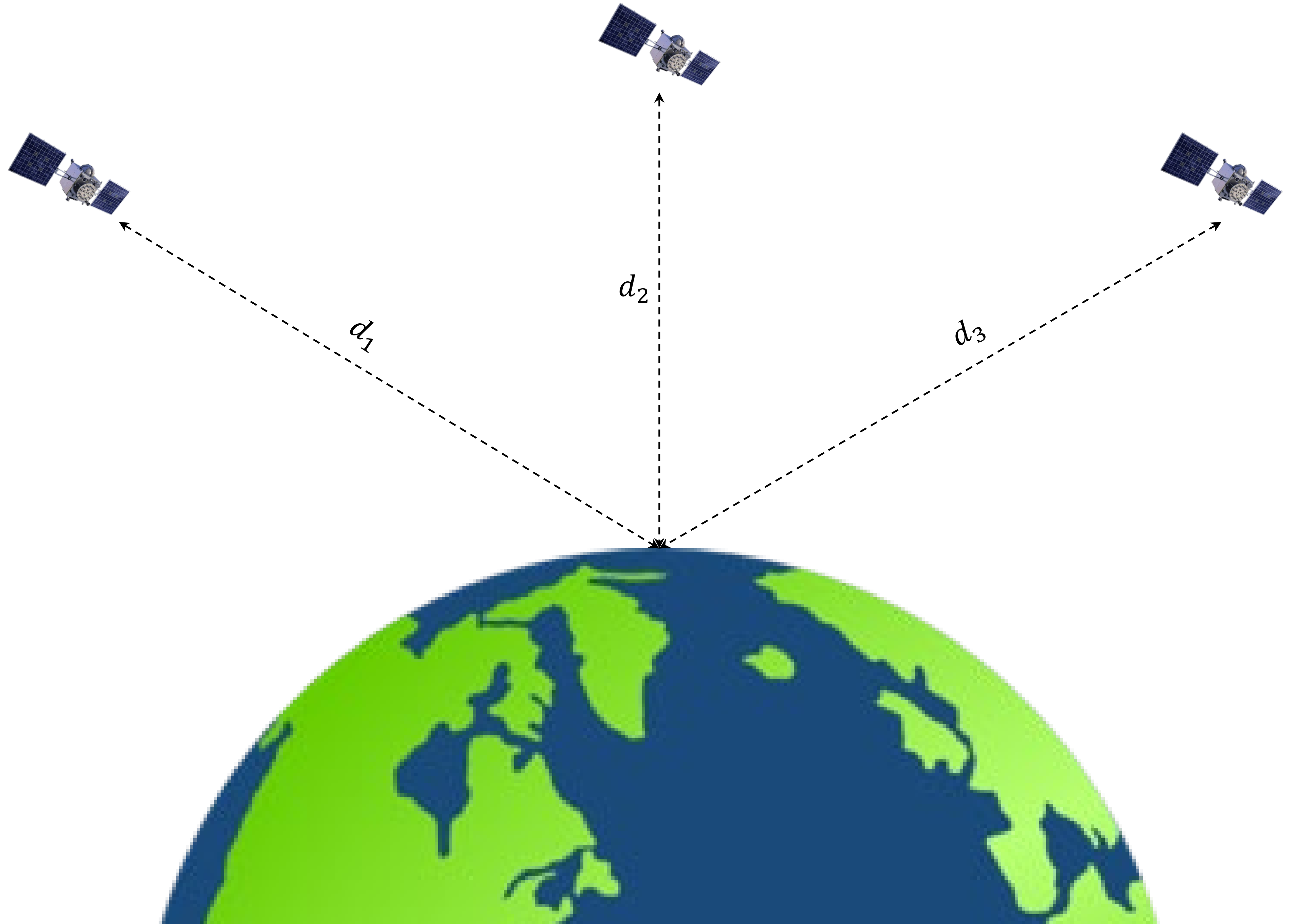
MIT MAS S62 – Ocean IoT


Medium earth orbit
~ 20,200 km

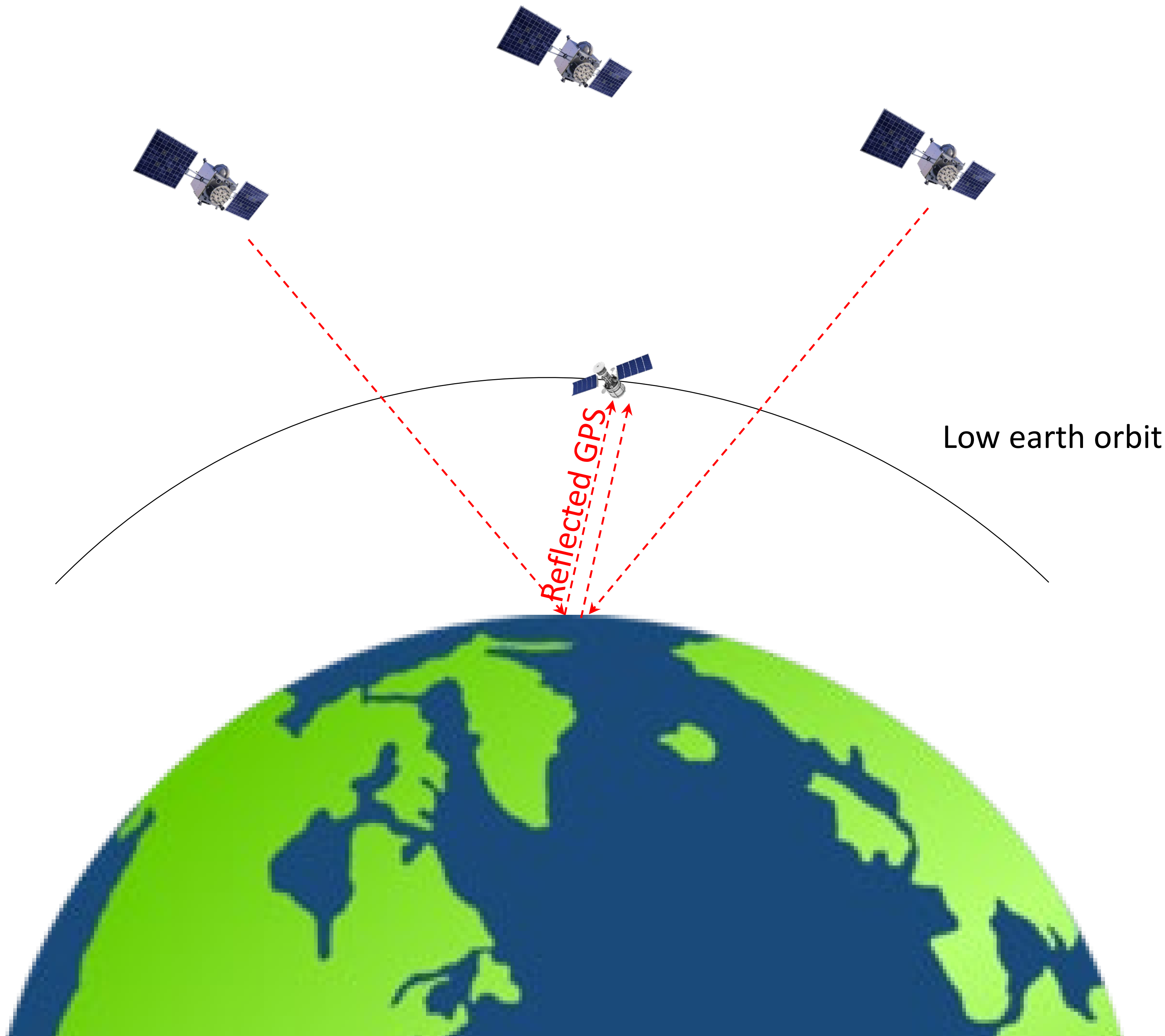

d_1



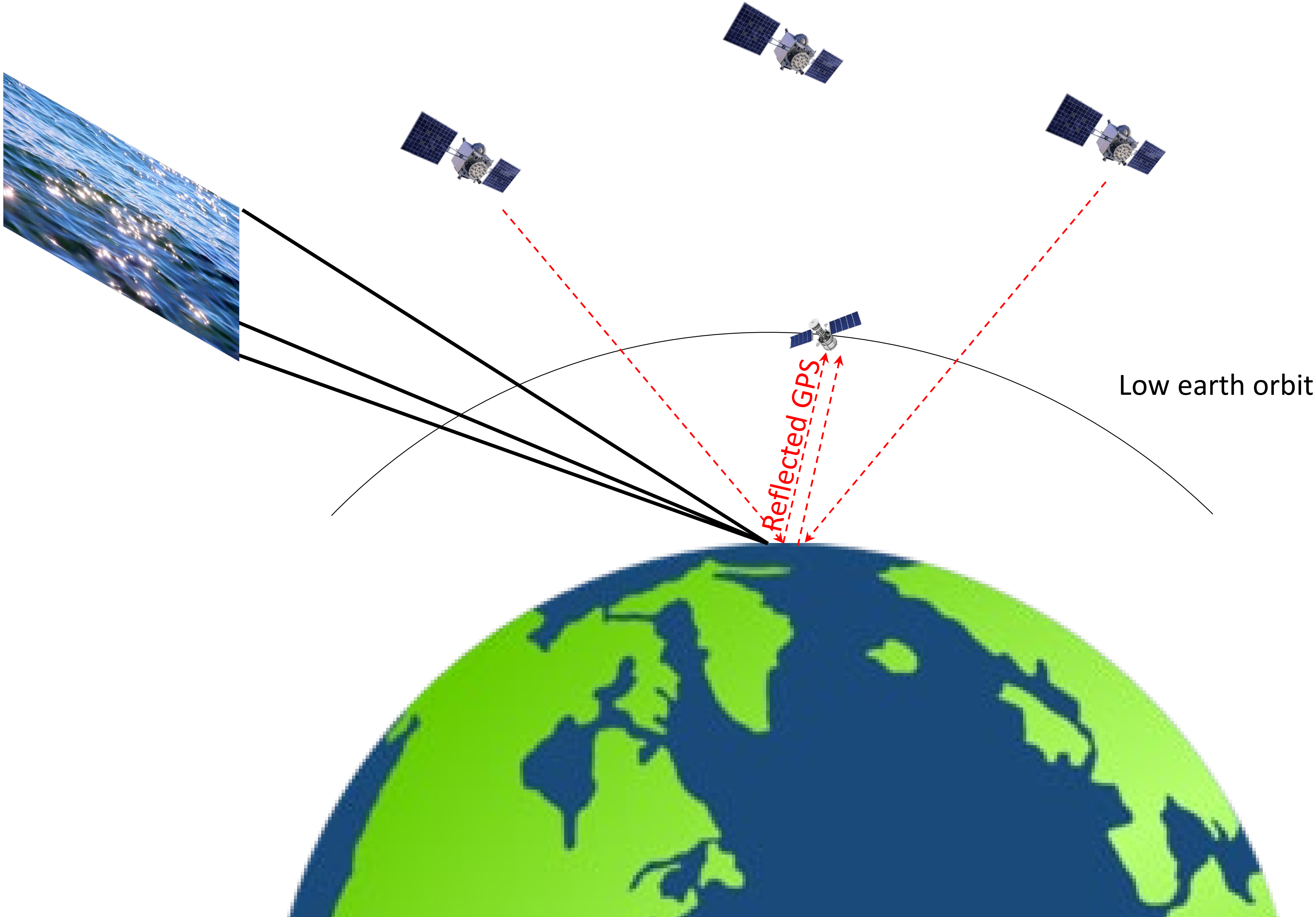
d_1
d_2



d_1
d_2
d_3

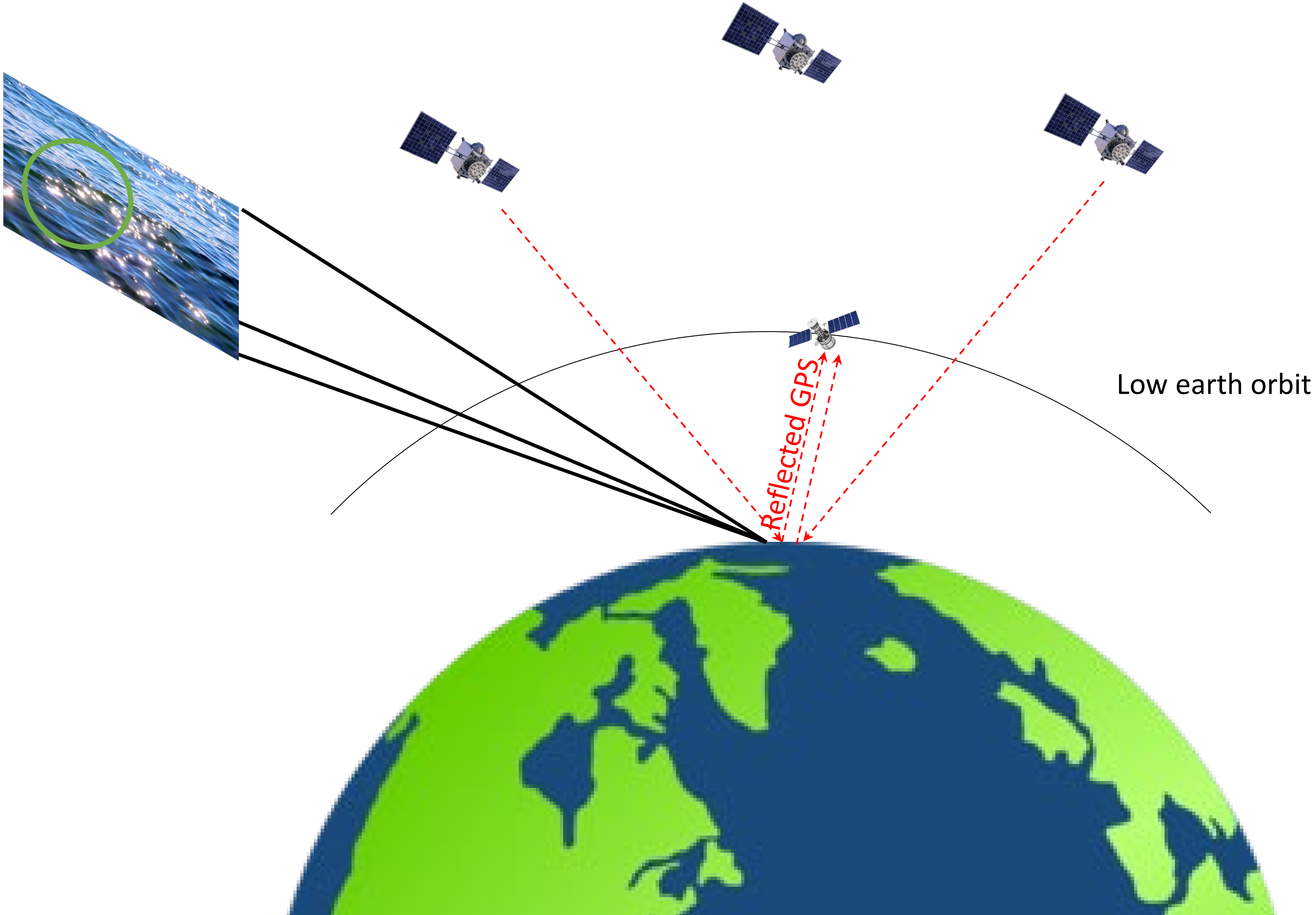


Reflected GPS
Low earth orbit


Reflected GPS
Low earth orbit

Can we track the movement of specular reflections with GPS signals?

If so, can we estimate surface wind speed?



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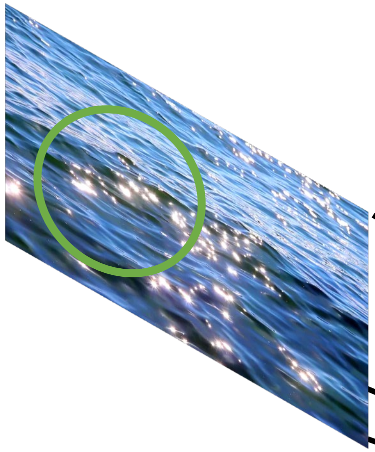
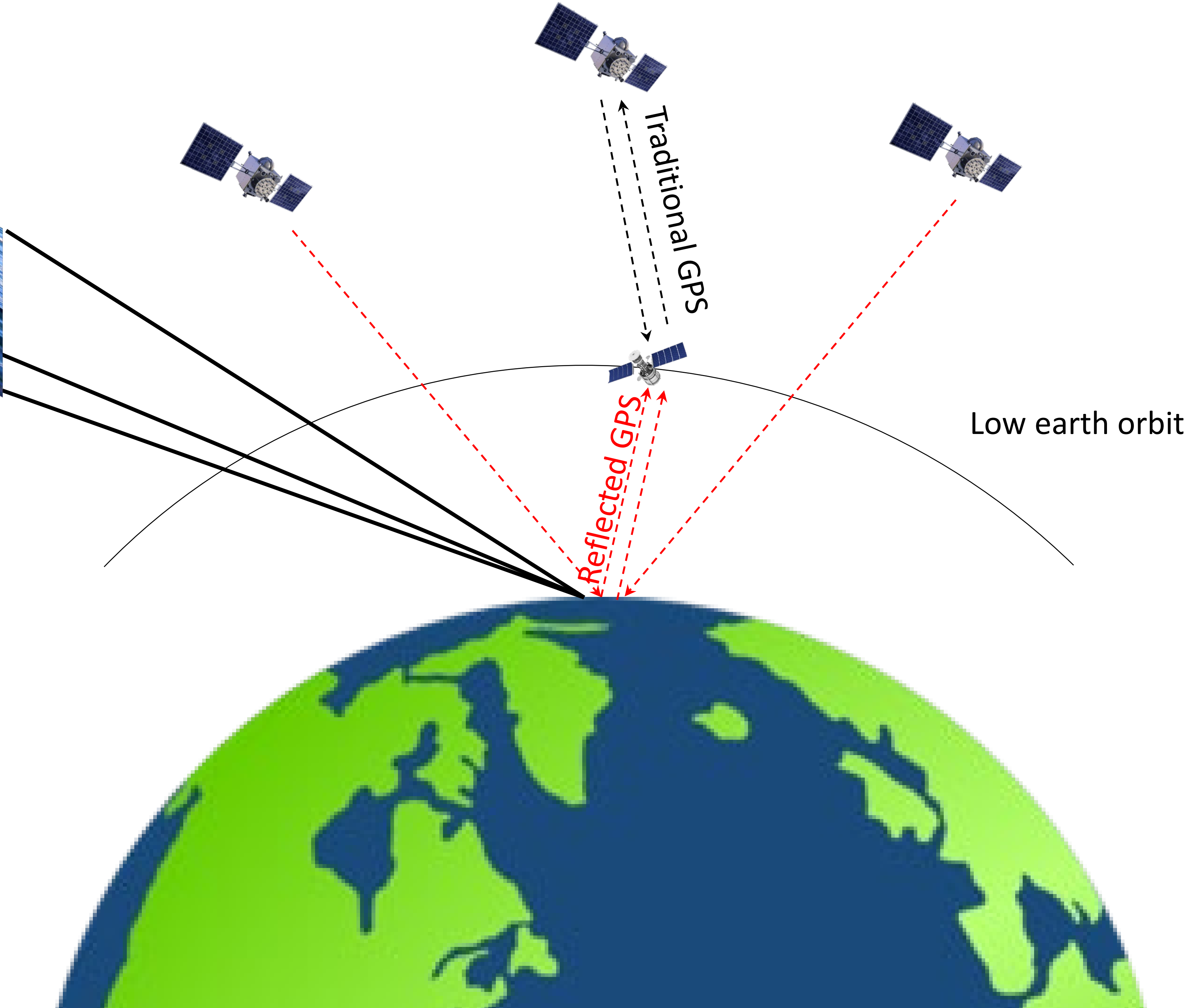
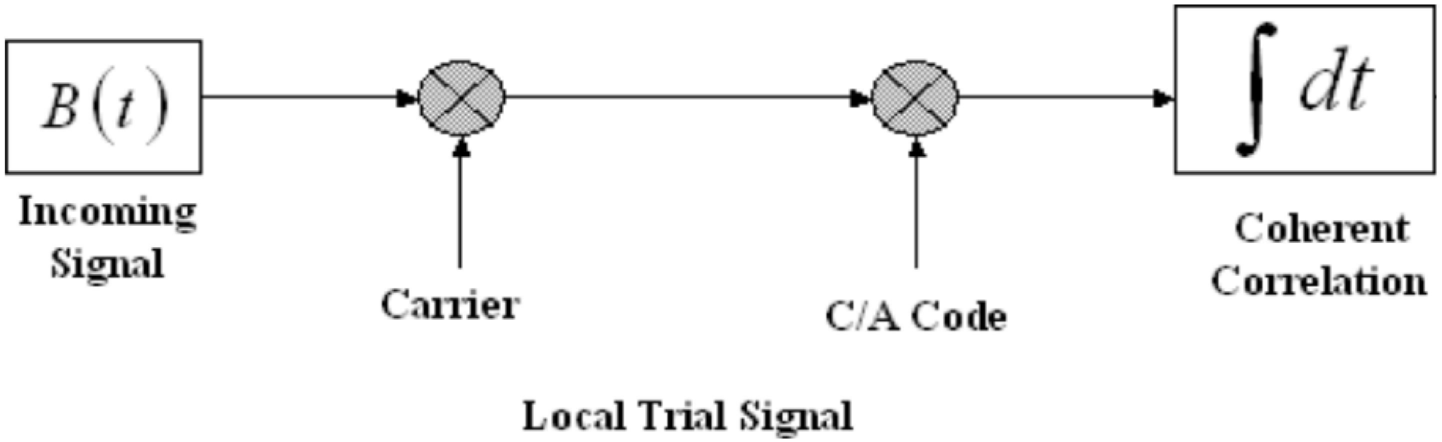


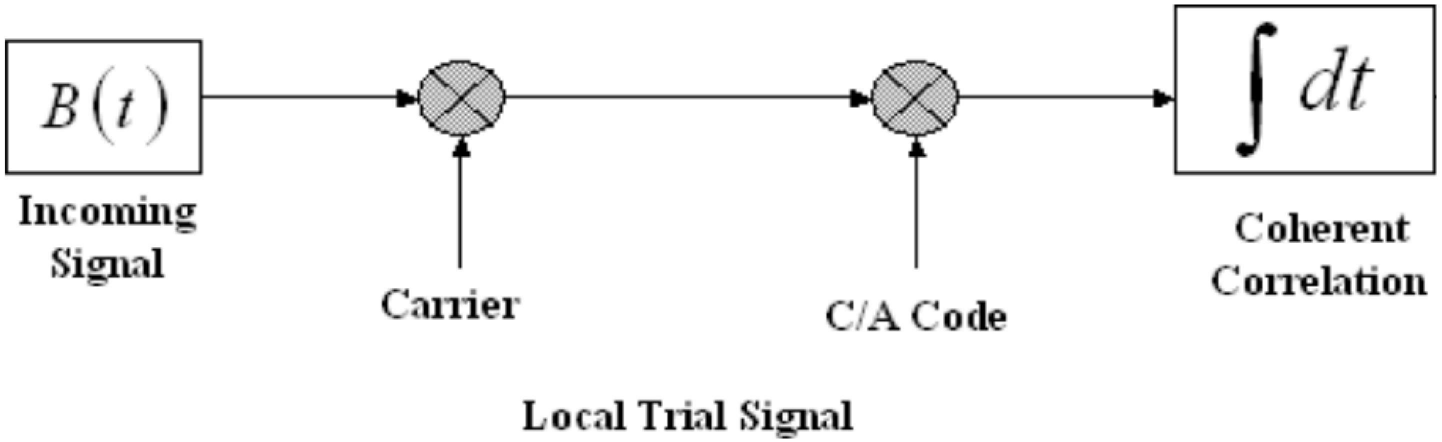


- Experiments run on United Kingdom’s Disaster Monitoring Constellation (UK-DMC)

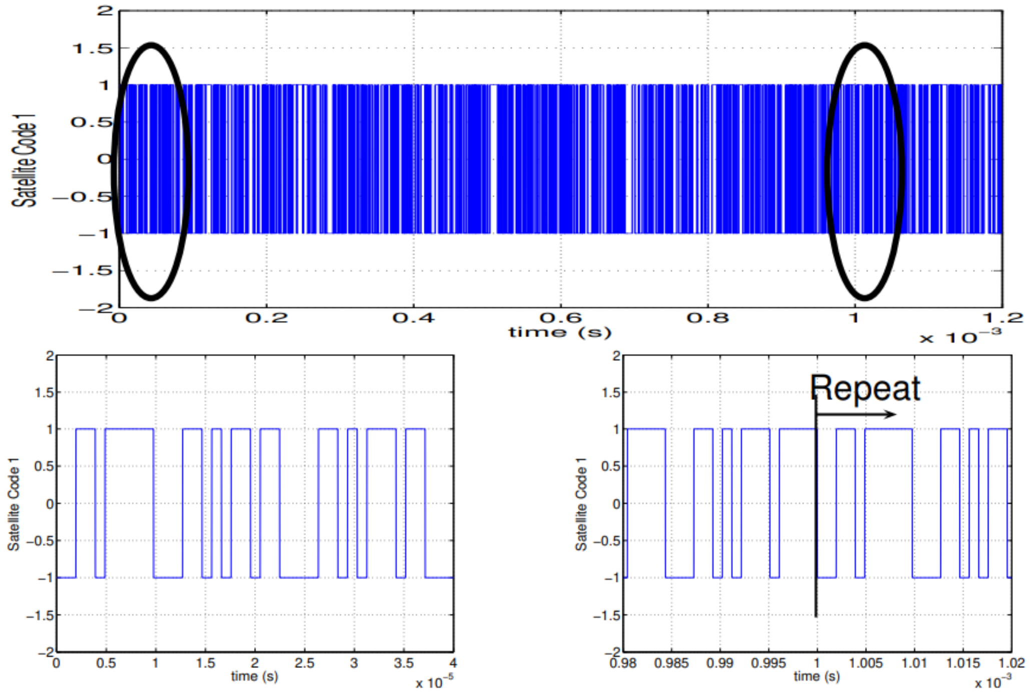
- Satellites implement a downward facing antenna and two upward facing antennas for traditional GPS operations



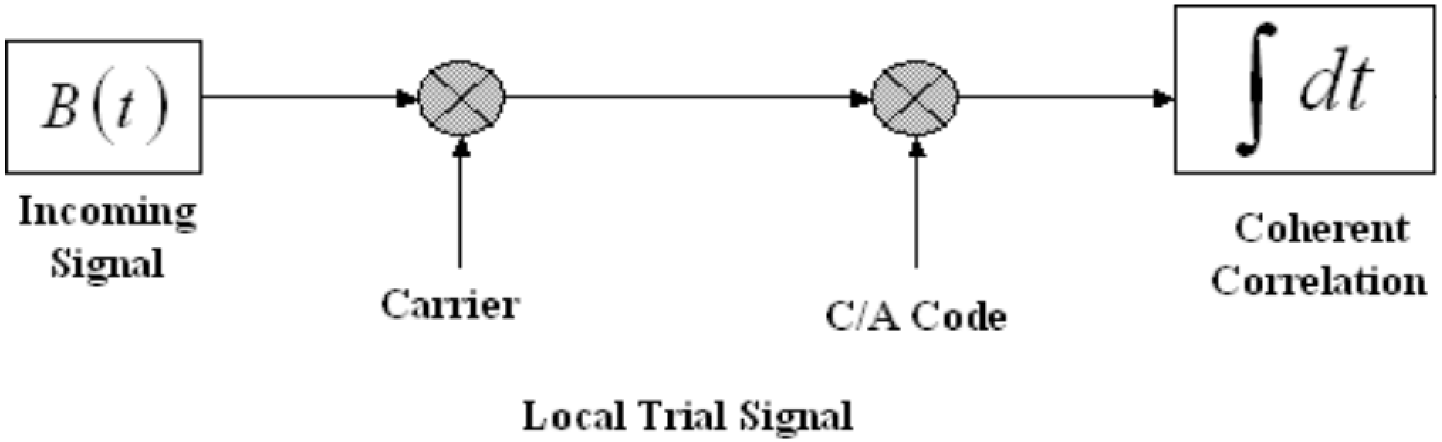
Gold code waveform

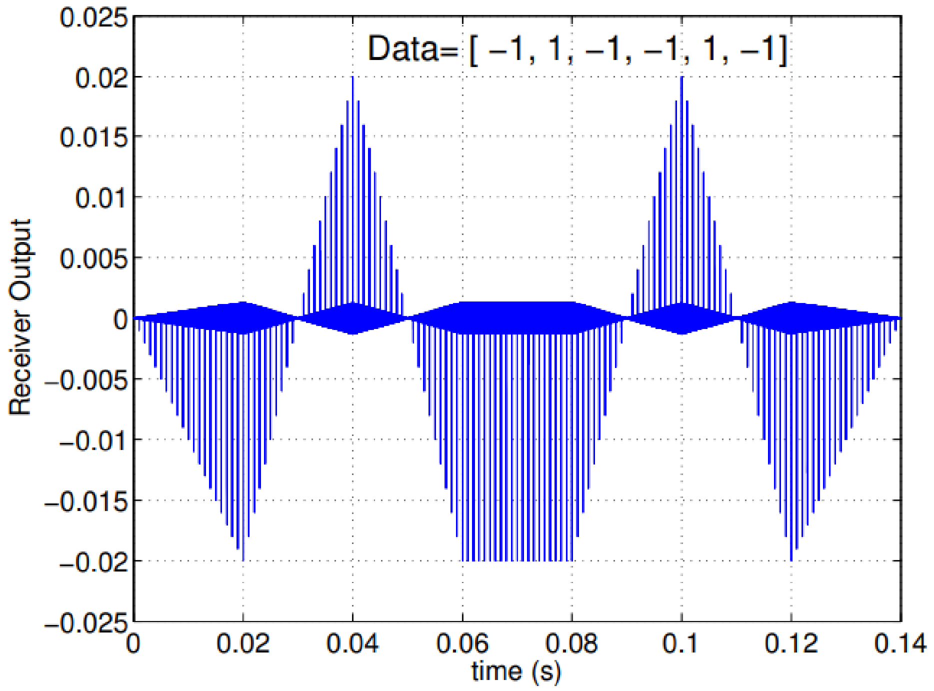


- C/A code = Coarse acquisition code
- Data rate is 50 bps
- Each data bit is modulated by 1023 “chips” per 1 ms
- Gold code repeats 20 times per data bit
- Gold code is unique to each satellite
- Gold code is **highly orthogonal**, meaning its autocorrelation is designed to be nearly zero everywhere except at delay = 0

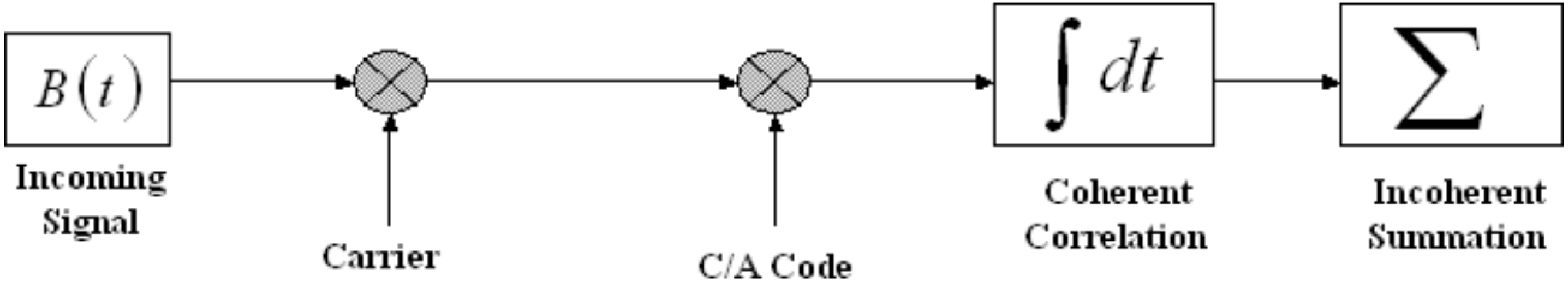


Gold code waveform

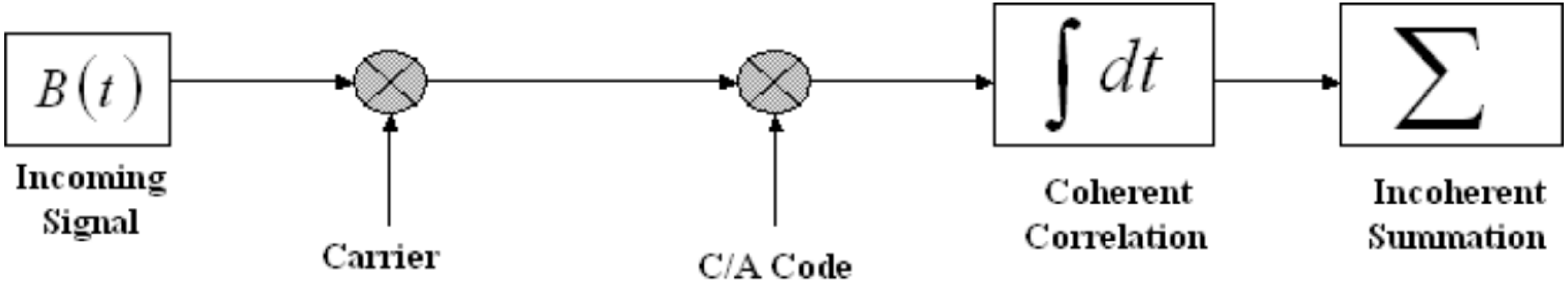




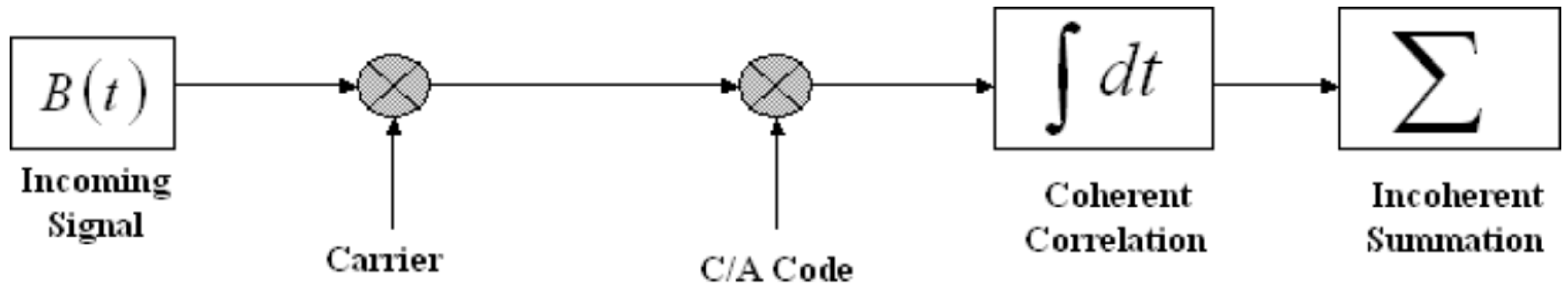
Receiver correlation with unique satellite gold code



B(t)
Incoming Signal
Carrier
C/A Code
∫ dt
Coherent Correlation
∑
Incoherent Summation



Multiple trial values of τ_T are used for the unique satellite C/A code



Multiple trial values of τ_T are used for the unique satellite C/A code

Each of the τ_T values used are then averaged, or integrated and divided by # of trial values

No averaging

10-correlation average

100-correlation average

1000-correlation average

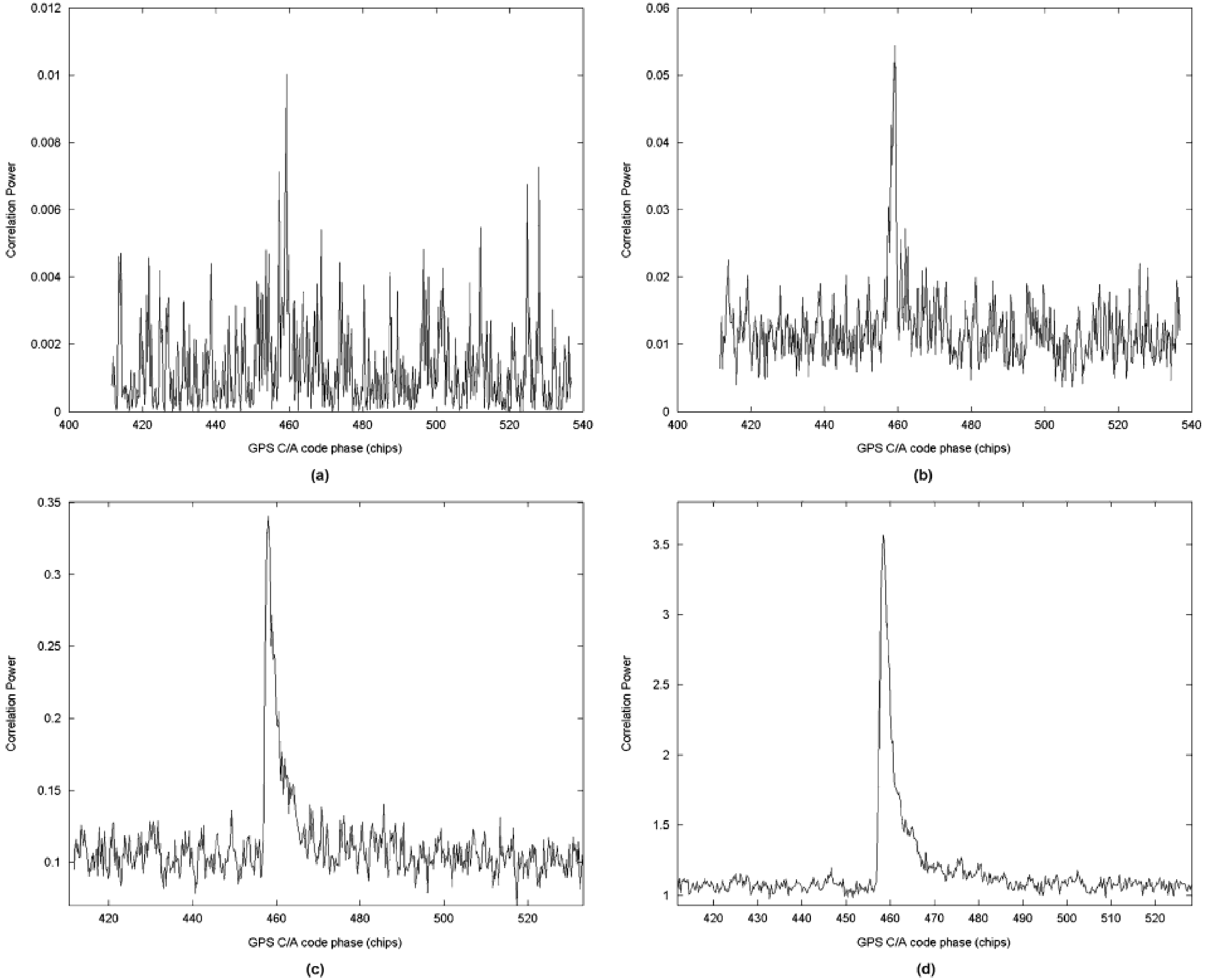
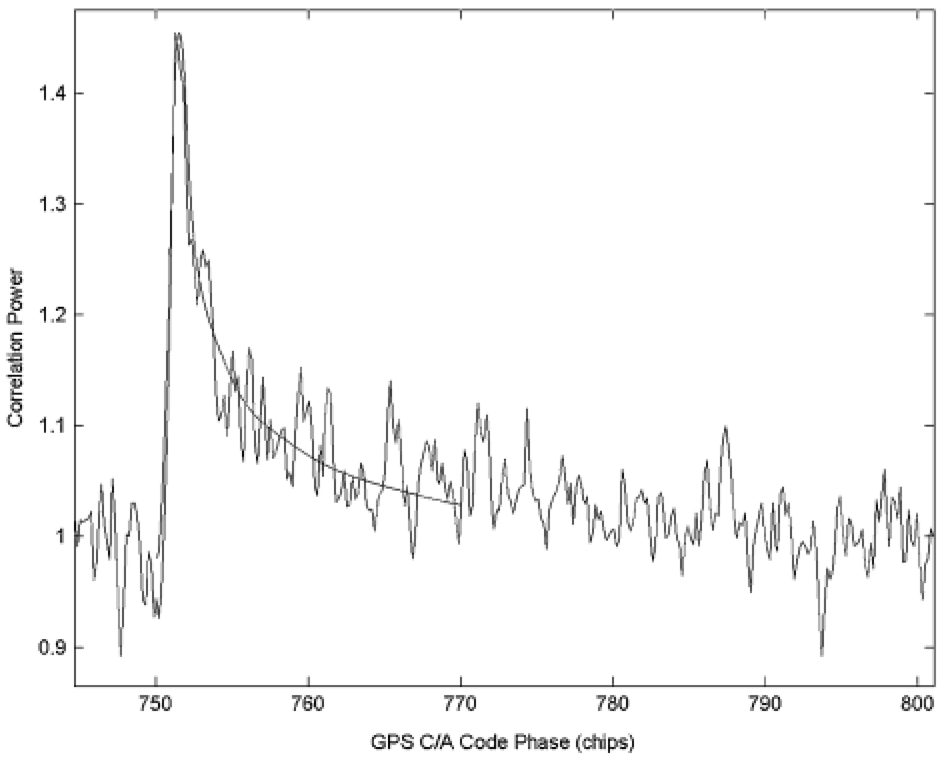
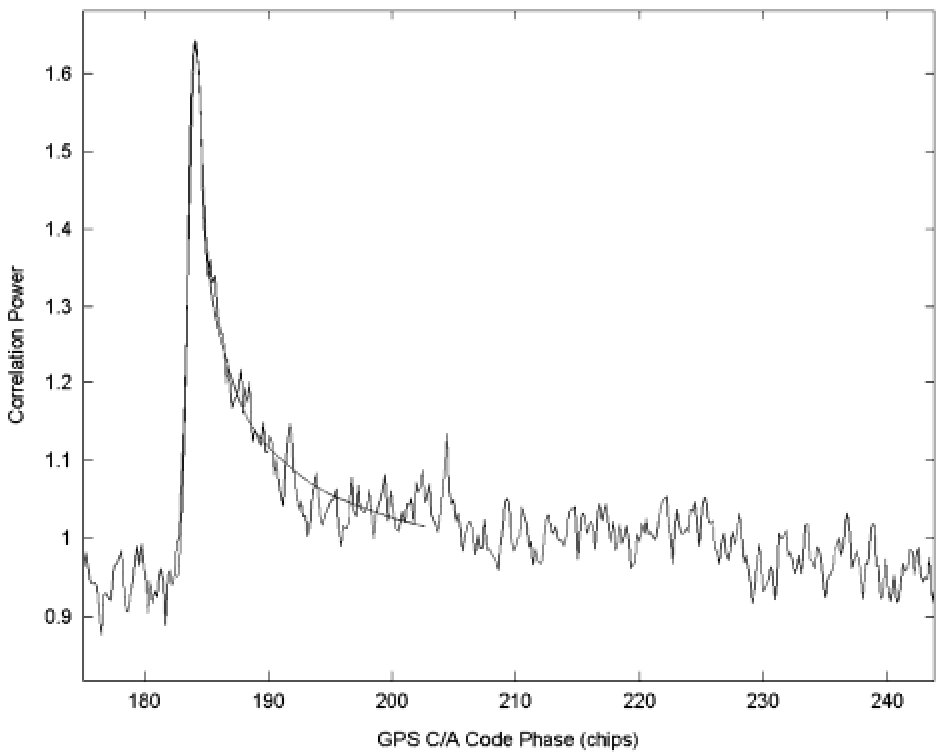
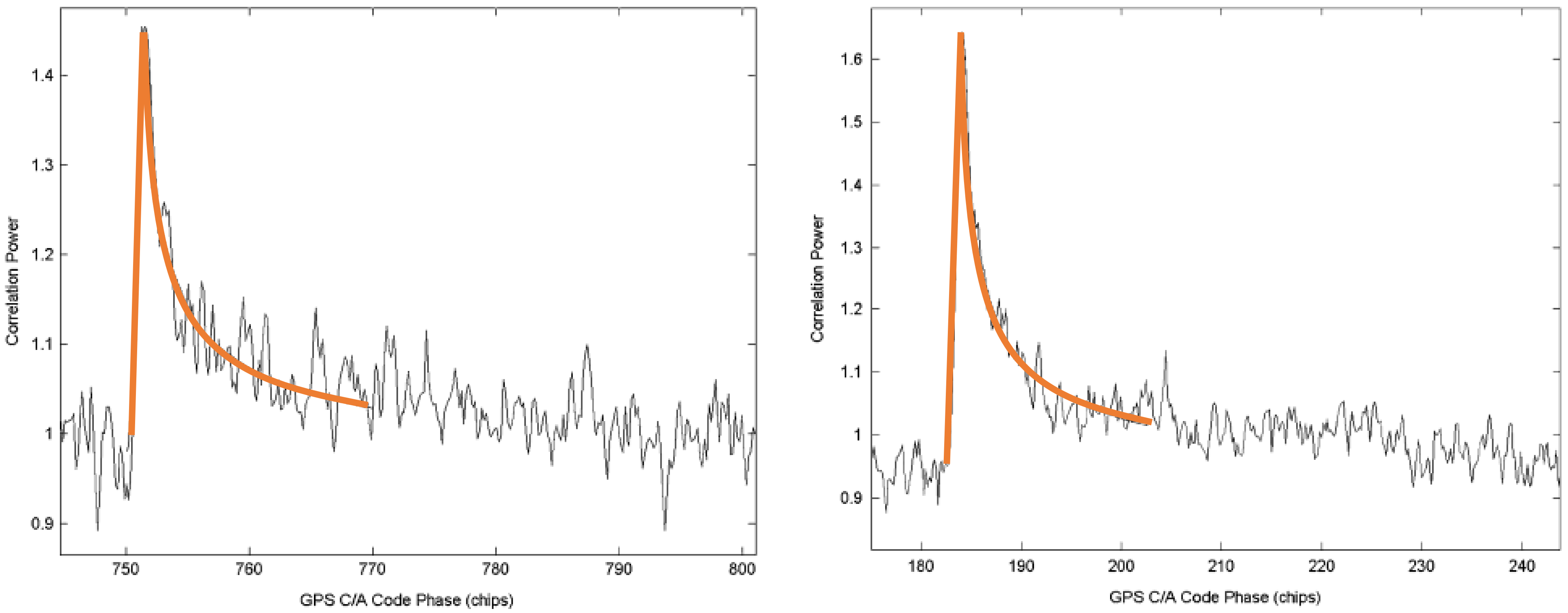


Fig. 5. (Left to right) Signal found in March 12 dataset, for GPS satellite PRN 28, using noncoherent integration times of (a) 1 ms, (b) 10 ms, (c) 100 ms, and (d) 1 s.





Averaged correlations fit to a model for ocean scattering, known as the
Zavorotny/Voronovich ocean scattering model



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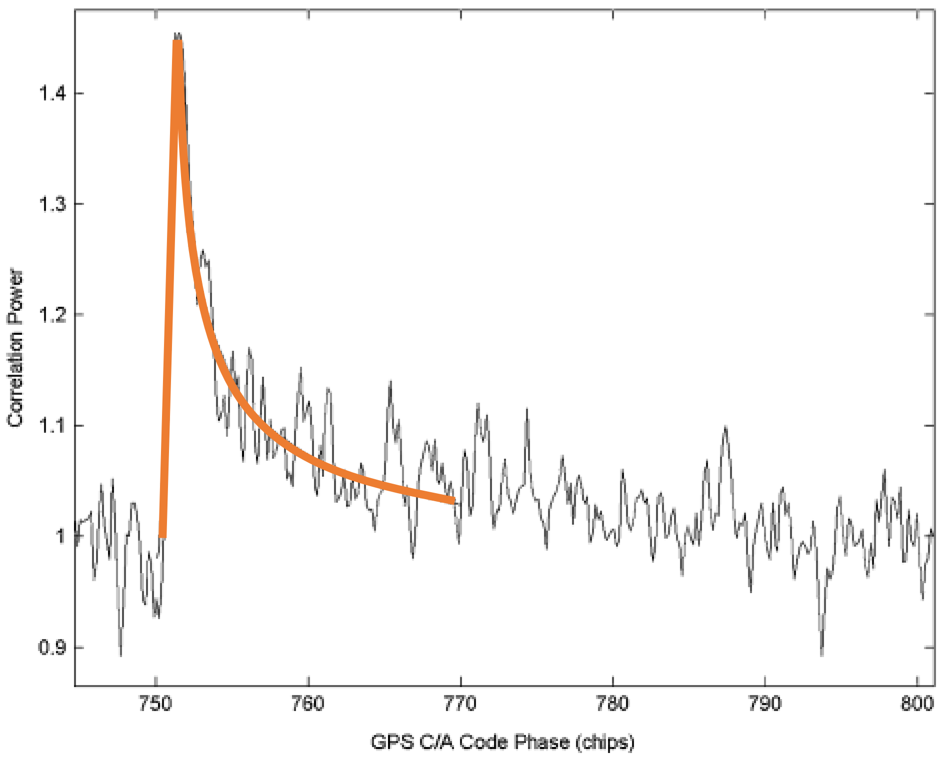

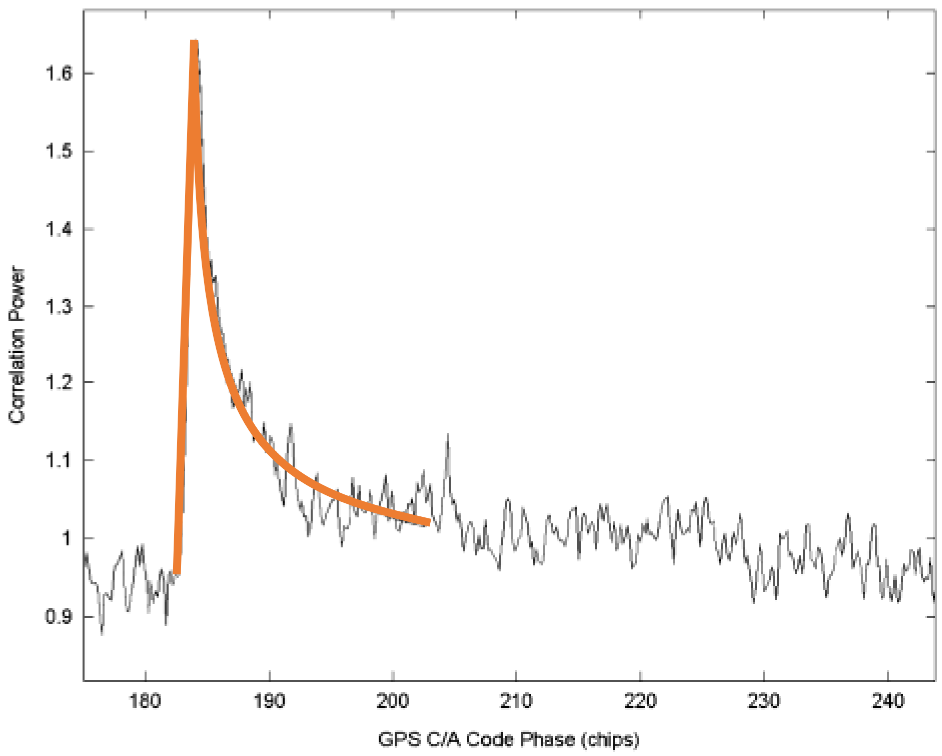

Averaged correlations fit to a model for ocean scattering, known as the **Zavorotny/Voronovich ocean scattering model**

Elfouhaily ocean wave spectrum used to generate sea condition inputs to ocean scattering model

Date	PRN	Wind Estimate ECMWF	Wind Estimate QuikSCAT	Model Estimated Wind Speed
21st May 2004	29	6.3 m/s	7.7 - 8.0 m/s	7.1 m/s
	26	5.3 m/s	5.9 - 6.8 m/s	8.9 m/s
24th May 2004	29	6.2 m/s	10.8 - 11.8 m/s	13.2 m/s
	26	5.3 m/s	7.3 - 8.0 m/s	14.0 m/s
3rd June 2004	29	6.7 m/s	6.7 - 6.9 m/s	14.1 m/s
	26	6.5 m/s	6.4 - 6.6 m/s	9.7 m/s

- Two GPS signals detected PRN 29 and PRN 26
- “Ground truth” wind speed estimates generated using an existing ocean monitoring satellite scatterometer, QuikSCAT
- Secondary “ground truth” wind estimates generated using outputs from the European Centre for Medium Range Weather Forecasting (ECMWF)

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Some agreement?

Inaccurate and inconsistent

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Conclusion

- GPS signals can be detected from reflections off the ocean surface
- Wind speed estimates can be made from these measurements
- Existing ocean monitoring satellite networks are probably best suited for this application
    - Why use GPS? There don’t seem to be many benefits
- Wind speed estimates are both inaccurate, inconsistent, and compared against inexact times and locations