GPS

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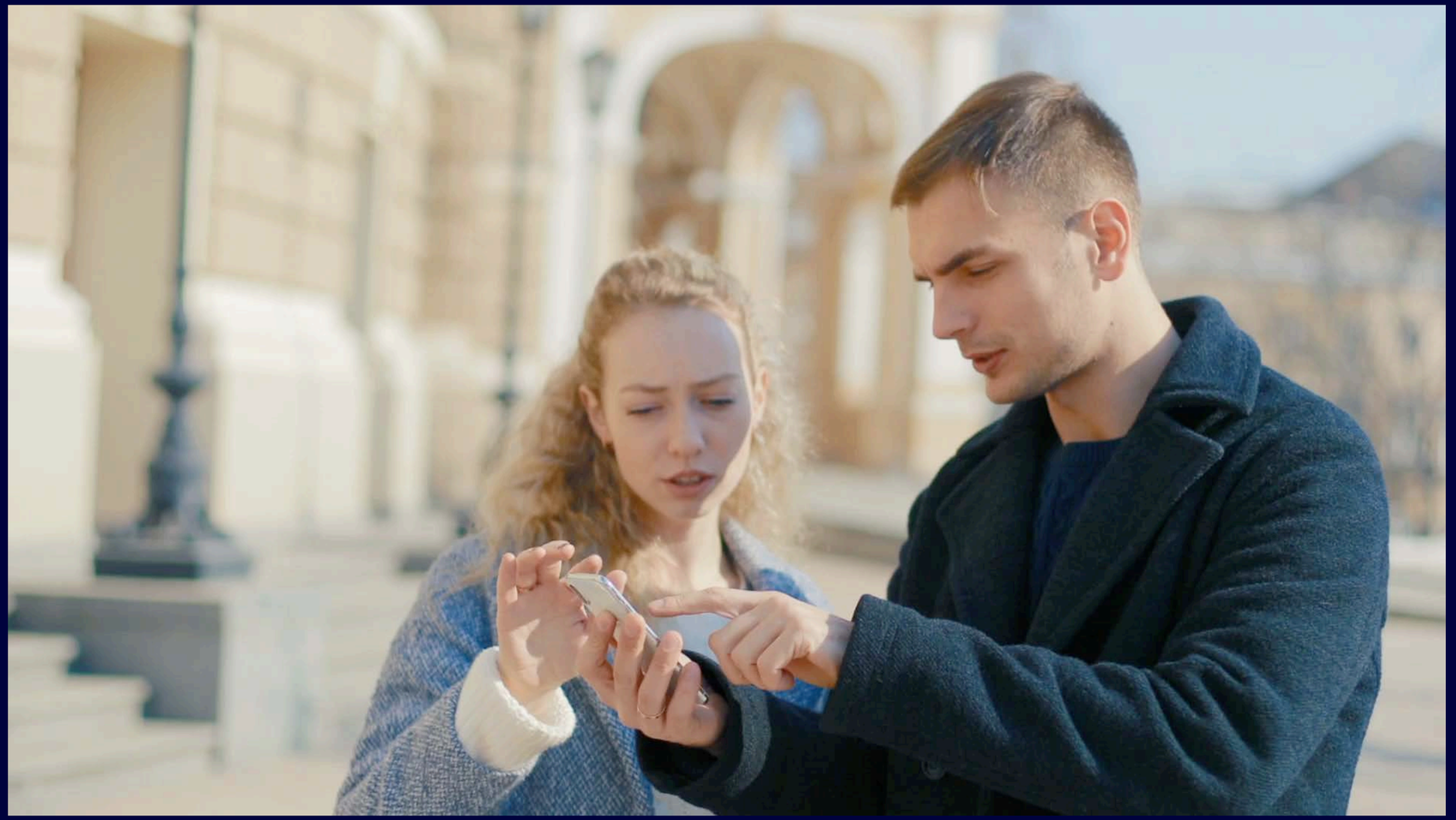
GPS



Harwich Woodbridg and Handfordwater with the Sands from Nazeland to Hosely Bay : To ye Hon.ble Samuel Pepys Esq.r Secretary of the Admiralty of England, President of ye Royall Society & Maister of ye Trinity House of Deptford. Strond / This Chart is Dedicated and Presented by Cap.t Greenvil Collins Hydrog.r to the King 1686 ; Herman Moll Sculp. by Collins, Greenville (16..-1696 ?). Cartographe - 1686 - Bibliothèque nationale de France, France - No Copyright - Other Known Legal Restrictions.

GPS uses tri-lateration

- The GPS receiver in your phone or watch solves for
  - latitude; longitude; altitude and time

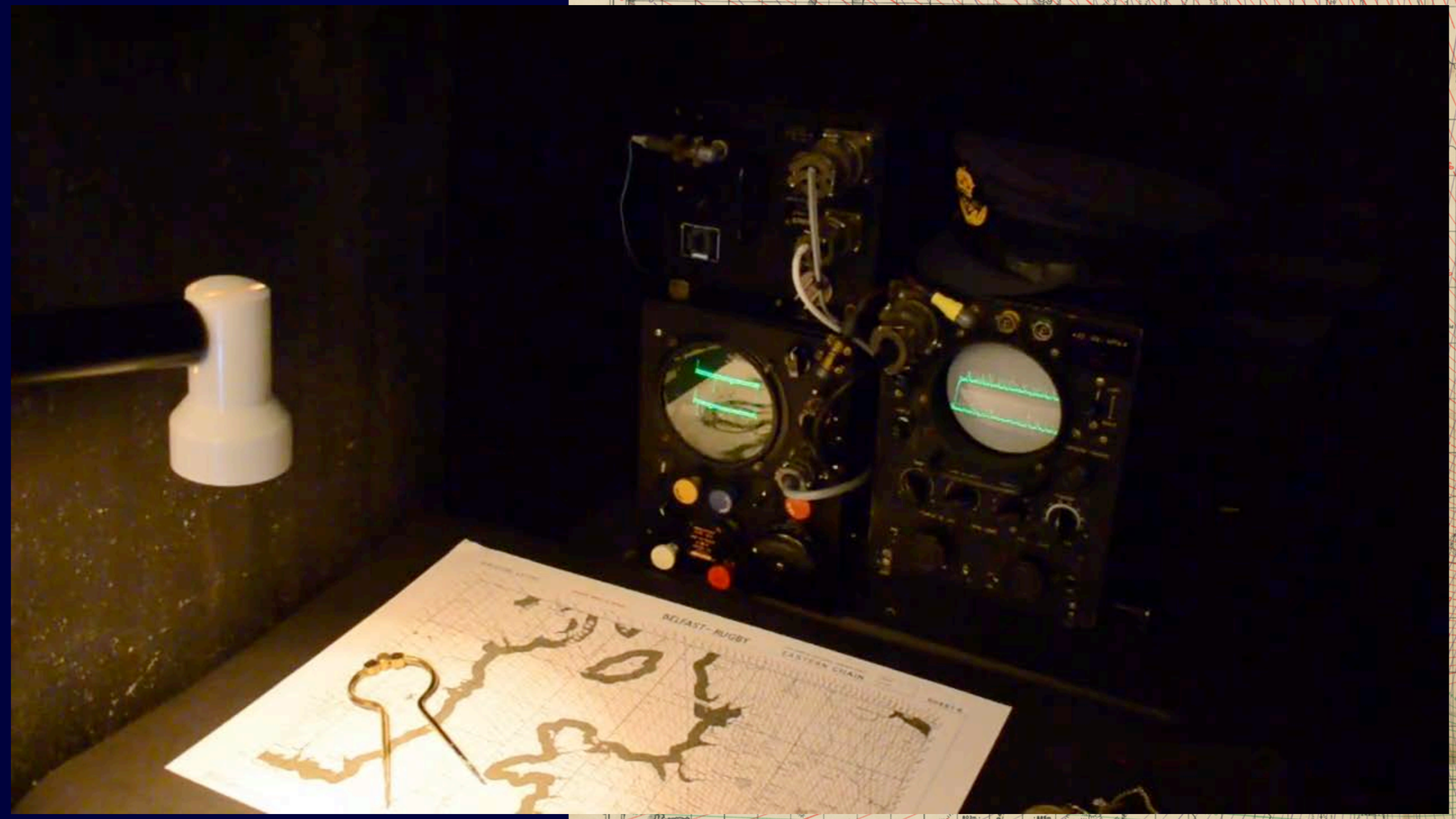
- Four variables requires a minimum of four satellites

- It uses the fact that radio waves travel at nearly the speed of light to measure the delays (or ranges) to the satellites

Gee

Map from mapchart.net

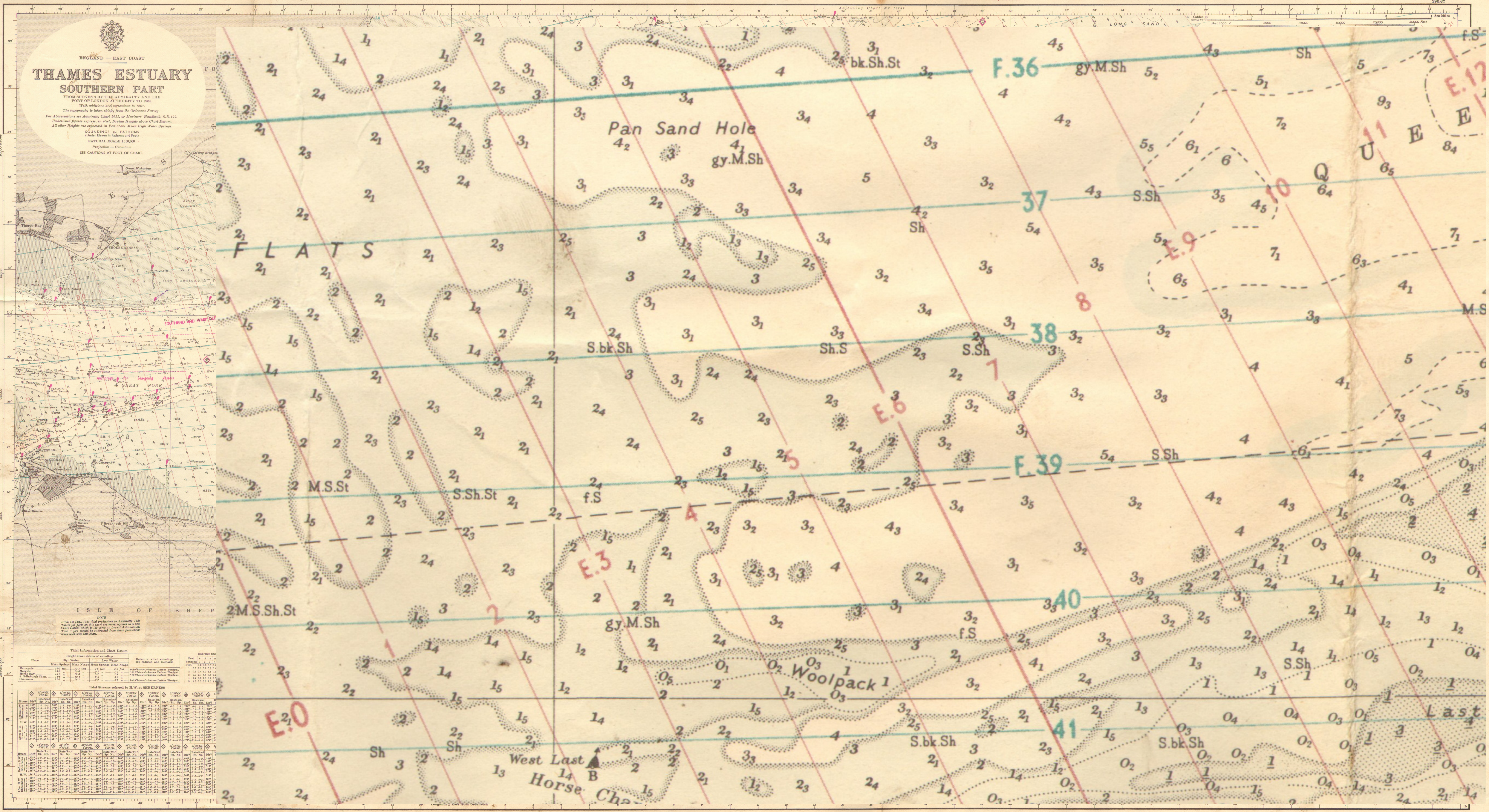
Gee map



The GEE Navigation System - a simple overview, The Radar Room,

https://www.youtube.com/watch?v=ycE3U8sGpW0

LARGER SCALE CHARTS (LATTICED OR UNLATTICED) MUST INVARIABLY BE CONSULTED. FOR NOTES ON FIXED & VARIABLE ERRORS OF THE DECCA SYSTEM SEE ADMIRALTY LIST OF RADIO SIGNALS, VOL. V.



DECCA CHART — CHAIN 5B/MP (English)

(AB.AC.)

L(D5)1607

GPS parameters

- L1 1.57542 GHz - civilian single channel
- L2 1.22760 GHz - military and dual-frequency (models ionosphere delays)

- Basic signal, the *carrier*, is a sine wave but it is *modulated* by the GPS information.

- GPS satellites vary the phase of the carrier according to if the information is zero or one.

GPS transmissions (simplified)

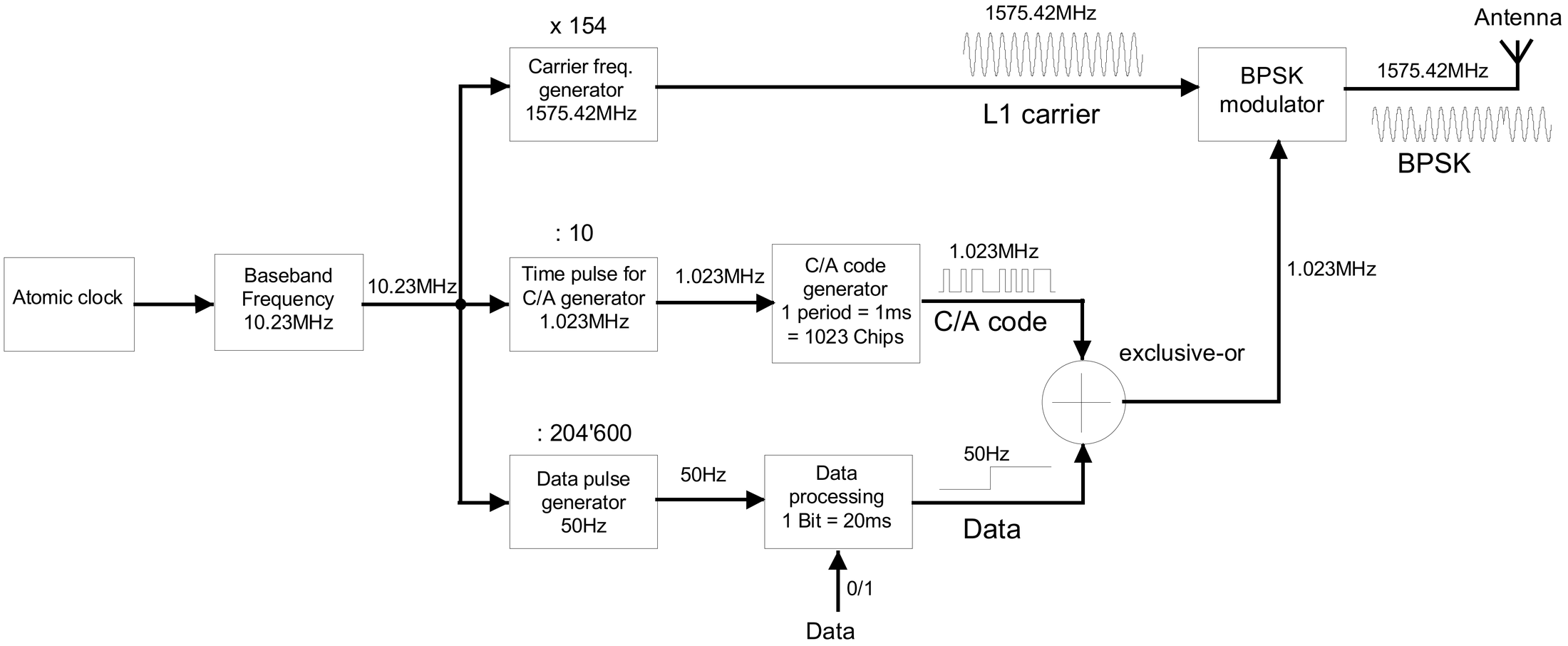
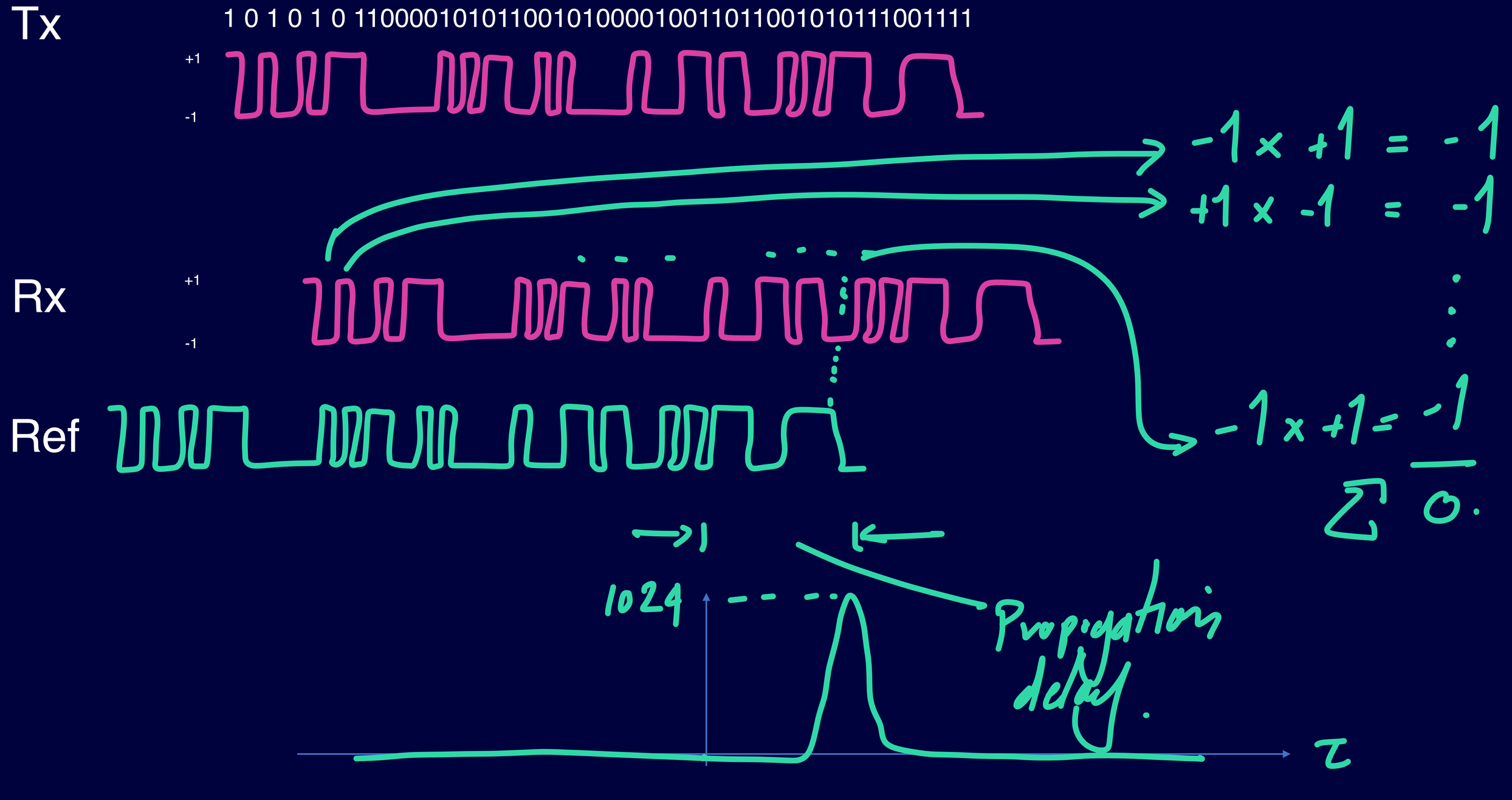


Figure 43 from GPS- Essentials of Satellite Navigation Compendium, report GPS-X-02007-D, U-Blox, , https://www.u-blox.com/en/ubx-viewer/view/GPS-Compendium_Book_(GPS-X-02007)?url=https%3A%2F%2Fwww.u-blox.com%2Fsites%2Fdefault%2Ffiles%2Fproducts%2Fdocuments%2FGPS-Compendium_Book_%2528GPS-X-02007%2529.pdf


Tx
1 0 1 0 1 0 1100001010110010100001001101100101011100111
+1
-1
Rx
+1
-1
Ref
-1 x +1 = -1
+1 x -1 = -1
-1 x +1 = -1
0.
1
1024
Propagation delay.
τ

GPS reception (simplifiec

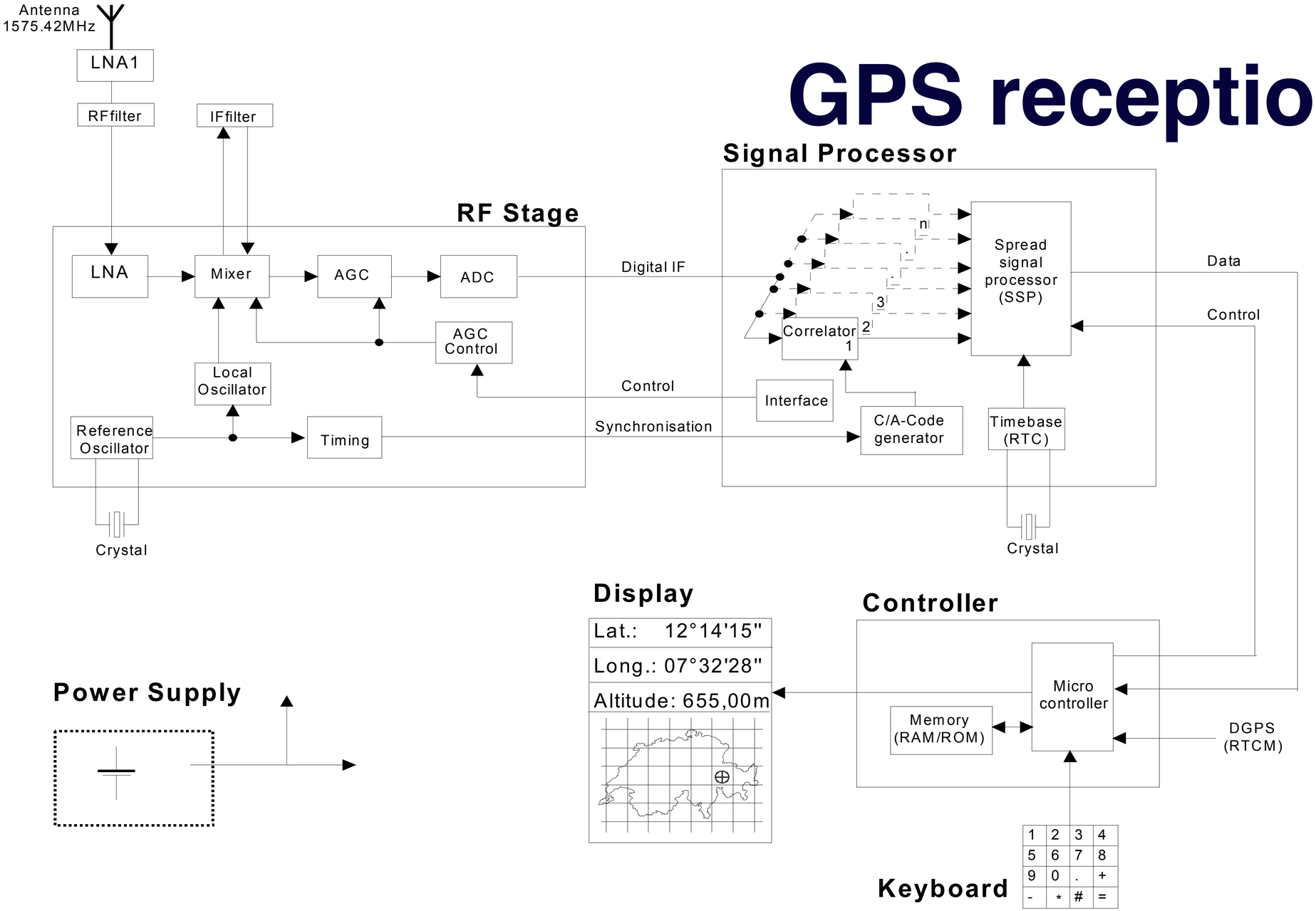
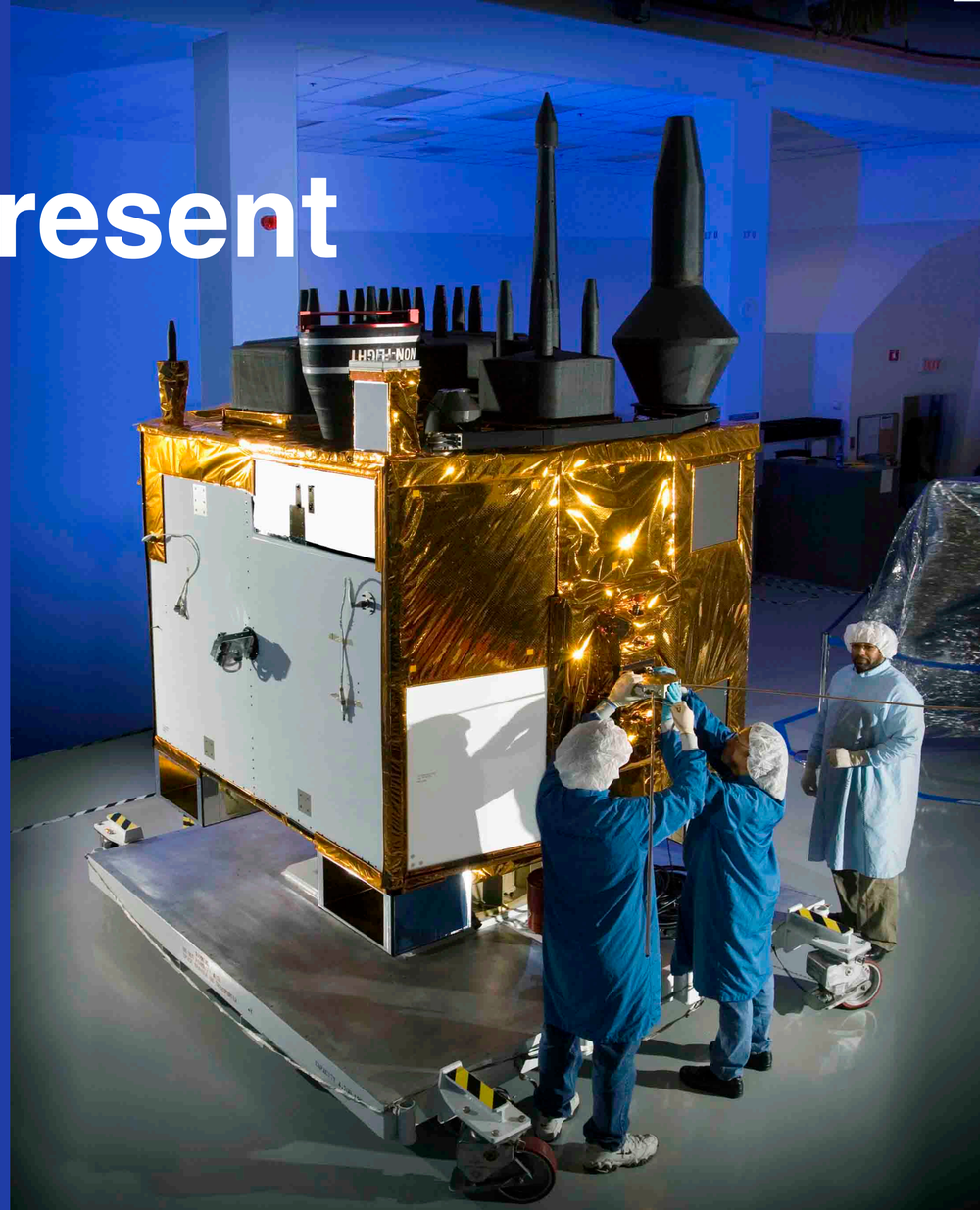


Figure 140 from GPS- Essentials of Satellite Navigation Compendium, report GPS-X-02007-D, U-Blox, , https://www.u-blox.com/en/ubx-viewer/view/GPS-Compendium_Book_(GPS-X-02007)?url=https%3A%2F%2Fwww.u-blox.com%2Fsites%2Fdefault%2Ffiles%2Fproducts%2Fdocuments%2FGPS-Compendium_Book_%2528GPS-X-02007%2529.pdf

GPS systems past and present



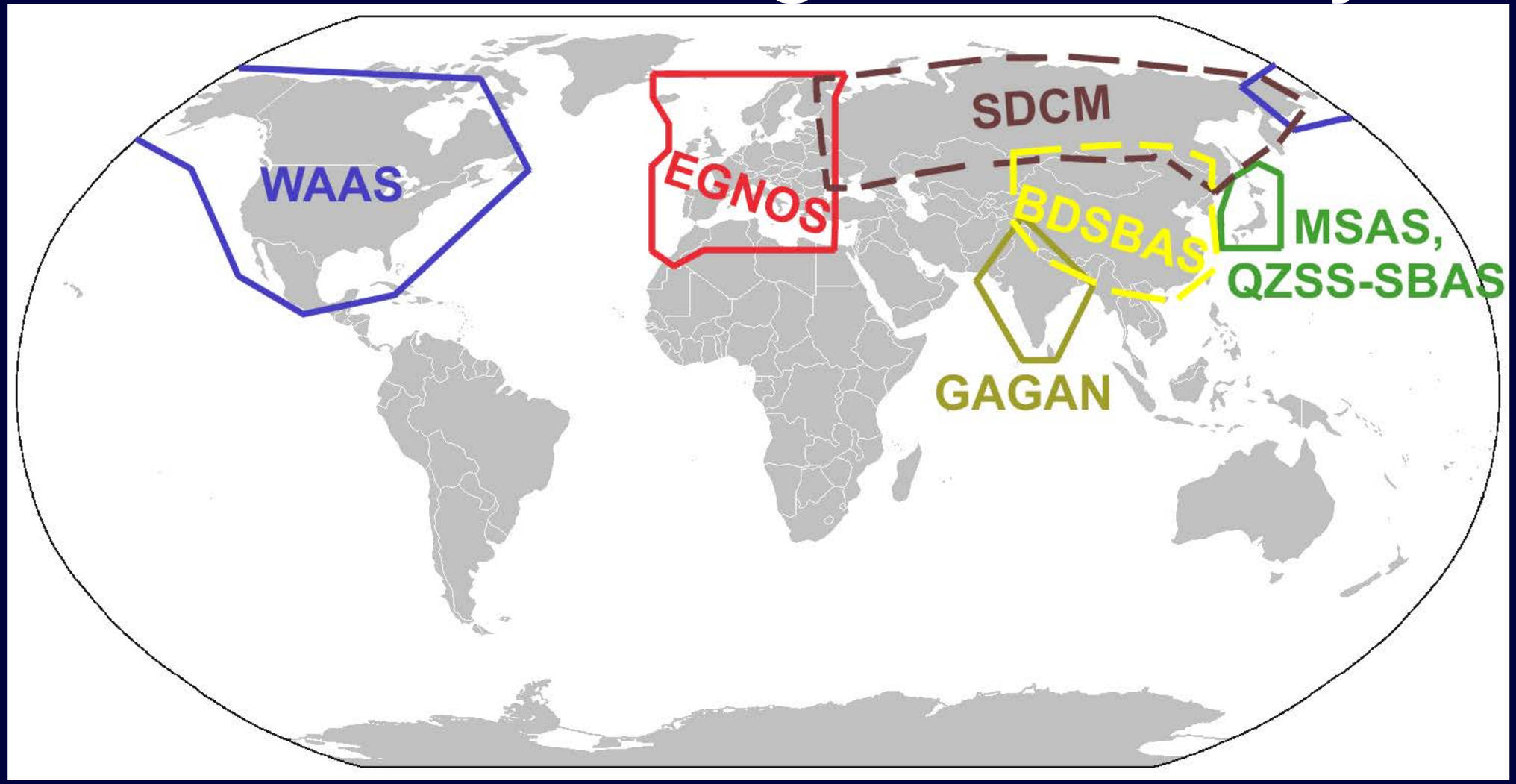
GPS Manpack from National Museum of American History https://americanhistory.si.edu/collections/search/object/nmah_1187729

GPS unsimplified

	IIA IIR	IIR-M	IIF	III/IIF
L5 1.17645 GHz			L5	L5
L2 1.22760 GHz	P(Y)	L2M P(Y) L2C	L2M P(Y) L2C	M+ P(Y) L2C
L1 1.57542 GHz	P(Y) C/A	L1M P(Y) C/A	L1M P(Y) C/A	M+ P(Y) L1C C/A
	< 2005	2005-2008	> 2008	> 2013

	Region of origin	Number of satellites (2021)	Year of first full operation	Coverage
GPS	USA	27	1993	World wide
GLONASS	Russia	23	1995	World wide
Galileo	EU	22	2016	World wide
Beidou	China	35 (5 geostationary)	2014	Regional - asia only
IRNSS(Navic)	India	8 (3 geostationary)	2018	Regional - S Asia
QZSS (Michibiki)	Japan	4 (1 geostationary and 3 elliptical)	2018	Region - Japan ad N Australia

Satellite Based Augmentation Systems



SBAS Service Areas by Persimplex https://commons.wikimedia.org/w/index.php?curid=18957671

GNSS failure modes

- Jamming
- Spoofing
- Space weather - Carrington Event 1859
- Space warfare

Jamming

Murrian, Matthew J., Lakshay Narula, Peter A. Iannucci, Scott Budzien, Brady W. O'Hanlon, Mark L. Psiaki, and Todd E. Humphreys, "First results from three years of GNSS Interference Monitoring from Low Earth Orbit," under review with NAVIGATION: Journal of the Institute of Navigation.

https://rnl.ae.utexas.edu/images/stories/files/papers/leo_int_mon.pdf

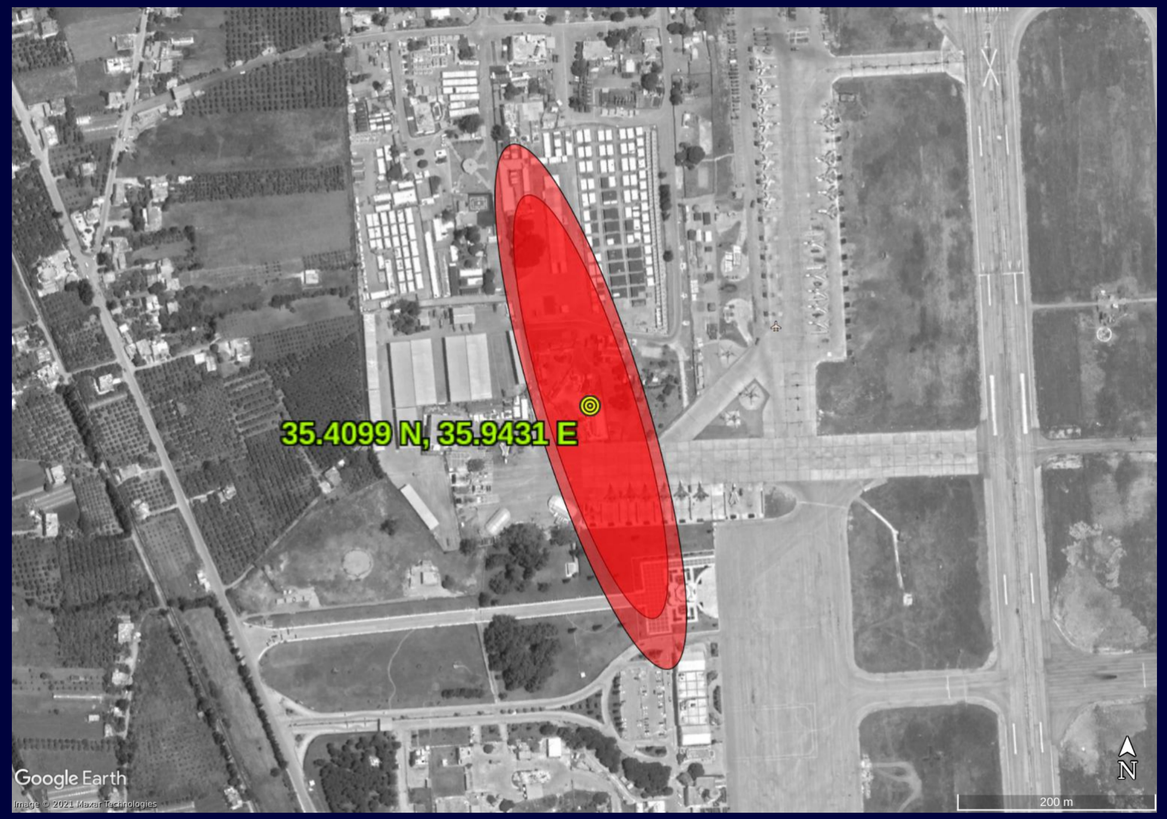
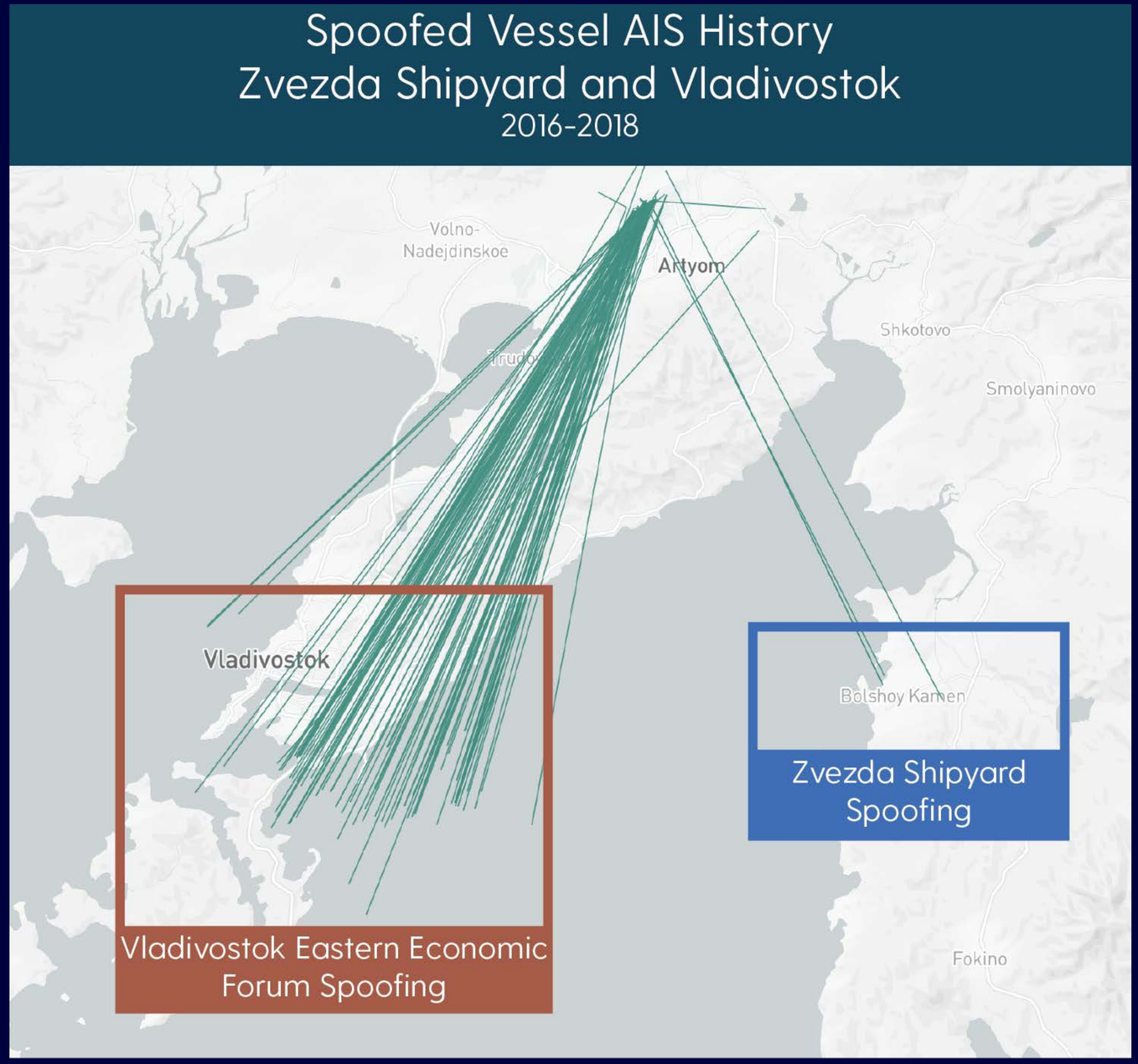


Fig. 6: Estimated transmitter location overlaid on formal-error 95% and 99% horizontal error ellipses. The location is coincident with an airbase on the coast of Syria. The semi-major axis of the 95% ellipse is 220 meters.

Spoofing



"Above us only the stars: exposing GPS spoofing in Russian and Syria, Center for Advanced Defense Studies Report 2019, https://www.c4reports.org/aboveusonlystars

What if GNSS were to fai

- Societal benefits estimated at £4 to £5 per £1 of public investment
- 5 day disruption to GNSS estimated at £5.2 Bn in UK
- Largest impact in emergency and justice services; road transport and maritime

“Economic impact to the UK of a disruption to GNSS, London Economics Report, 2017,

Cabinet Office

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Dr Ruth McKernan CBE
North Star House
North Star Avenue
Swindon
Wiltshire SN2 1UE
(SENT VIA EMAIL)

17 July 2017

Dear Dr McKernan

Re. Publication of ‘Economic impact to the UK of a disruption to GNSS’ report

I write to thank you for your letter of the 28th June highlighting the recent study from Innovate UK and others into the economic impact to the UK of a disruption to Global Navigation and Satellite Systems (GNSS), available on the GOV.UK website here.

I share your interest and concern regarding this issue and thank you for pursuing this important work. As Minister with responsibility for the resilience of the UK’s infrastructure, I am acutely aware that a disruption to satellite systems would affect the running of critical services. A broad range of sectors in the UK including the power grid, telecommunications networks, financial services, private and public transport including the maritime sector, emergency services and the military rely on this capability.

It is important to the UK Government therefore that an alternative to these satellite systems, which does not suffer from the same vulnerabilities, is established. Your letter and report notes that Enhanced Loran (eLoran), being a technologically dissimilar system, provides just such a resilient alternative to satellite systems. The UK Government is therefore supportive of any progress towards initiating and maintaining an operational eLoran network that can provide position, navigation and timing services and will lend support where appropriate to aid its establishment and continued use.

I understand that an in-depth UK Government review into the reliance of the UK’s Critical National Infrastructure on satellite systems is due to be published shortly. This review will make an important contribution towards informing the UK Government’s understanding of resilience to GNSS disruption.

I am copying this letter to the Government Chief Scientific Adviser and the Deputy National Security Adviser. A copy of this letter will also be published on the GOV.UK website.

Yours sincerely

Caroline Nokes

CAROLINE NOKES MP

The future of GNSS

- Fascinating geopolitics
  - which permanent member of the UN security council and/or G8 has no sovereign GNSS capability?
- Outdoor precision in good conditions now excellent
- Jamming countermeasures are primitive and receivers do not degrade gracefully
- From a wartime necessity to a global industry…

Next

Compression

23rd November 6pm (UK time) 2021

Thanks and kudos to the Worshipful Company of Information Technologists who sponsor these lectures.