Got Time for Alternate PNT?

Real-world results of a selection of alternate sources of the "T" to augment/back-up GNSS signals

WSTS May 2022

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Background & Acknowledgements

- Part of the work described here was undertaken as part of an EU/ESA funded research programme by Telespazio (UK) & Chronos Technology

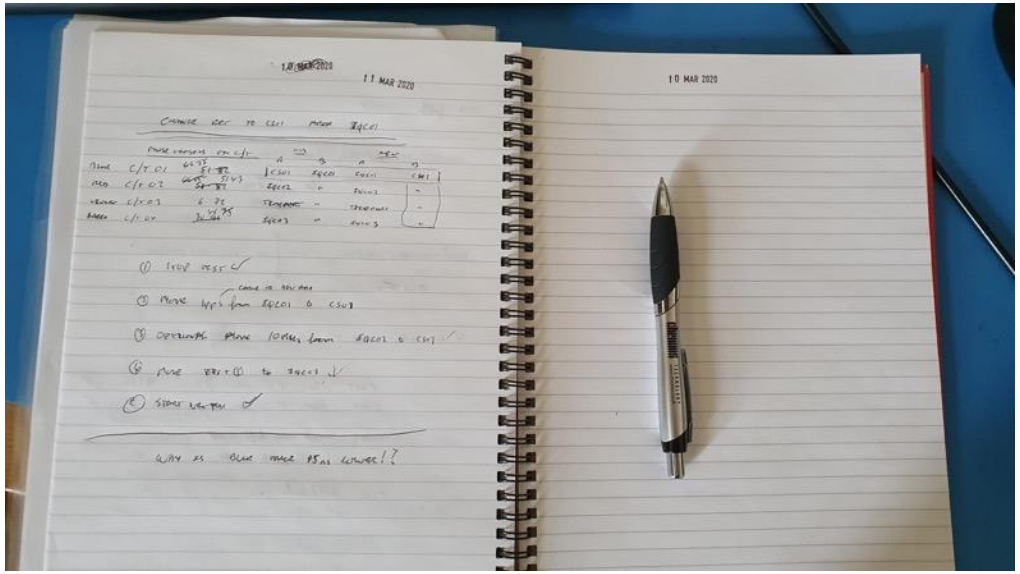
- Aims: Resilient, trustworthy, ubiquitous time transfer assessing alternative sources of time for a possible (future) hybrid timing receiver architecture

  https://navisp.esa.int/uploads/files/documents/NAVTIMING%20Final%20Presentation.pdf

  https://navisp.esa.int/project/details/102/show

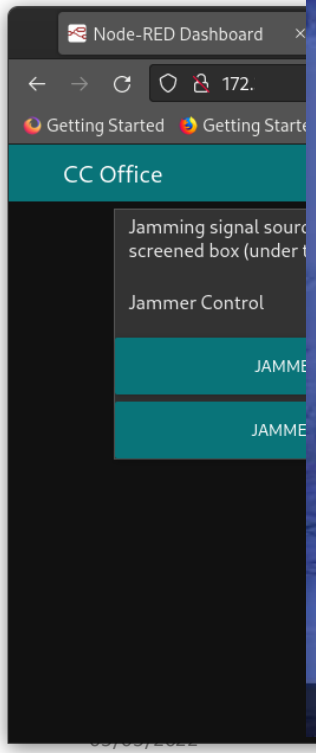
Lockdown(s) 2020

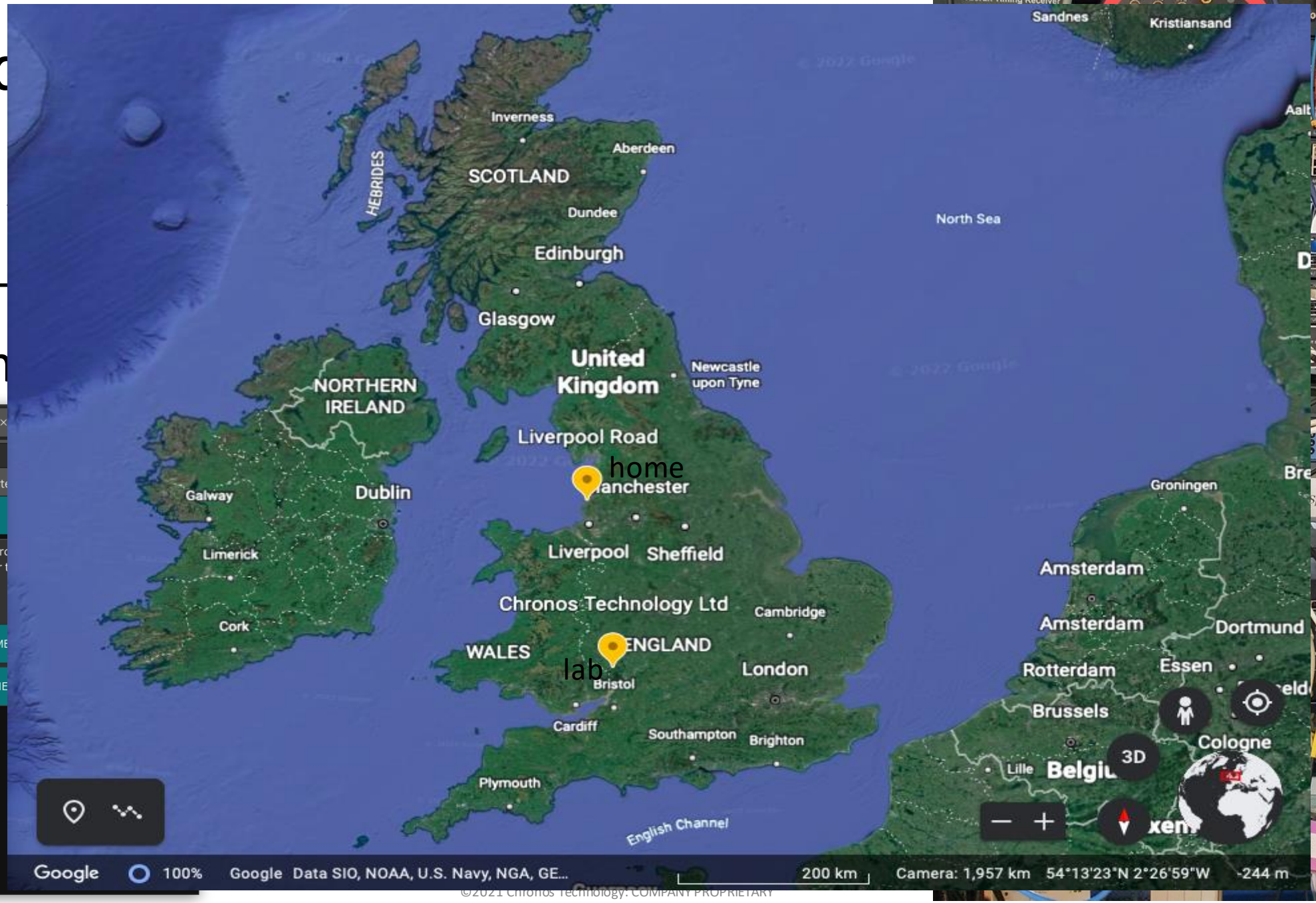
- Lab work started Aug 2020
  - lab logbook: last entry 10 MAR 2020 !



Locko

- Lab
- Rem





Scope: Alternative Sources Studied

- GNSS – MCMF ublox ZED-F9
  - Not really alternative, MCMF nature
- CSAC (as datasheet)
  - As low power holdover
- LF - eLORAN 100kHz (Tx faulty 6-7ms offset +6.7ppb)
- LF – BBC R4 198kHz
- LoRa
  - Proprietary timing messages gateway ←→ mote
- STL (Satelles/Iridium)
  - 1000x (30dB) higher signal strength vs. typical GNSS
- 5G (not lab based)
  - SSB GSCN/EARFCN etc. – GNSS proxy

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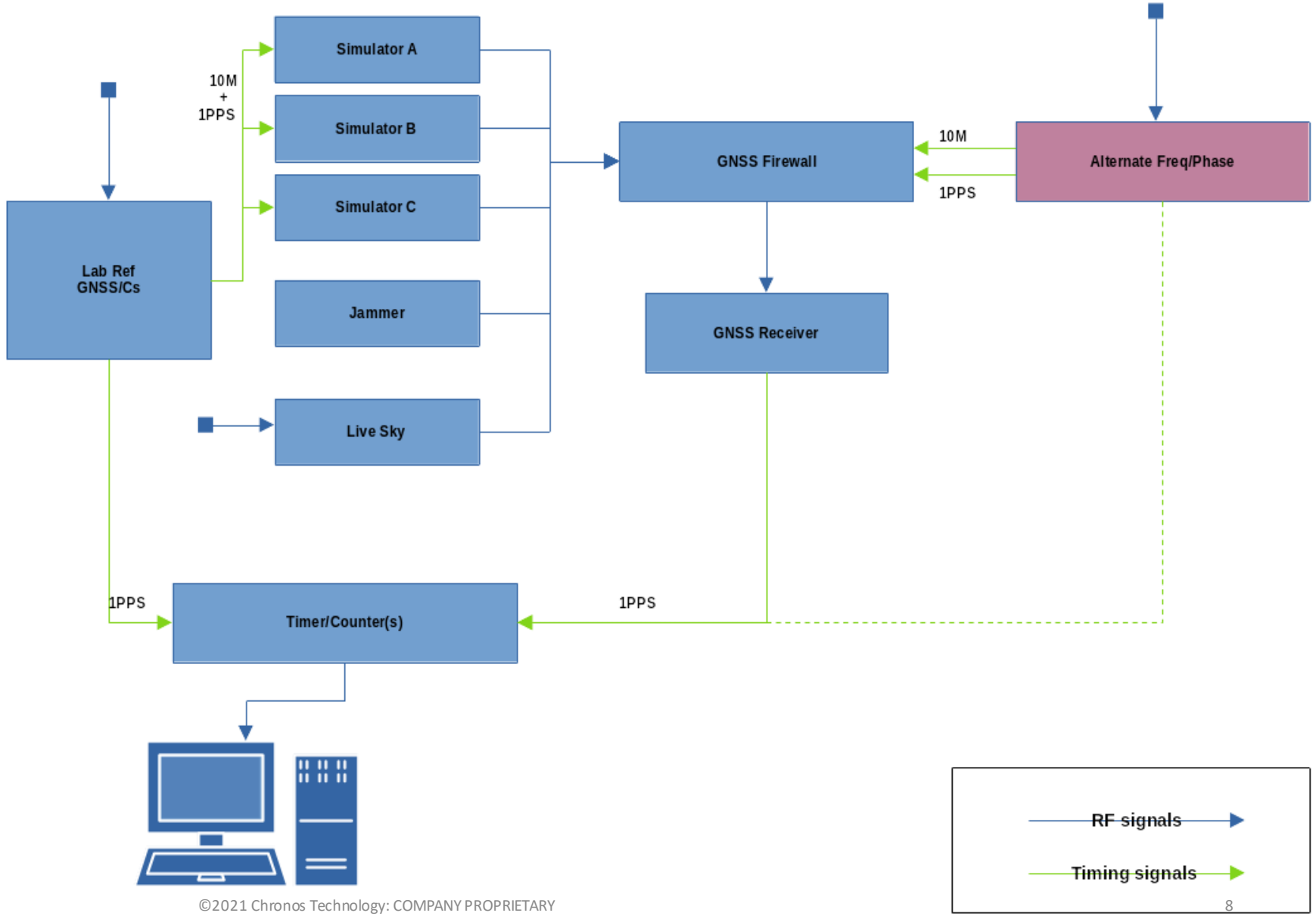
Results in the slide deck but not presented

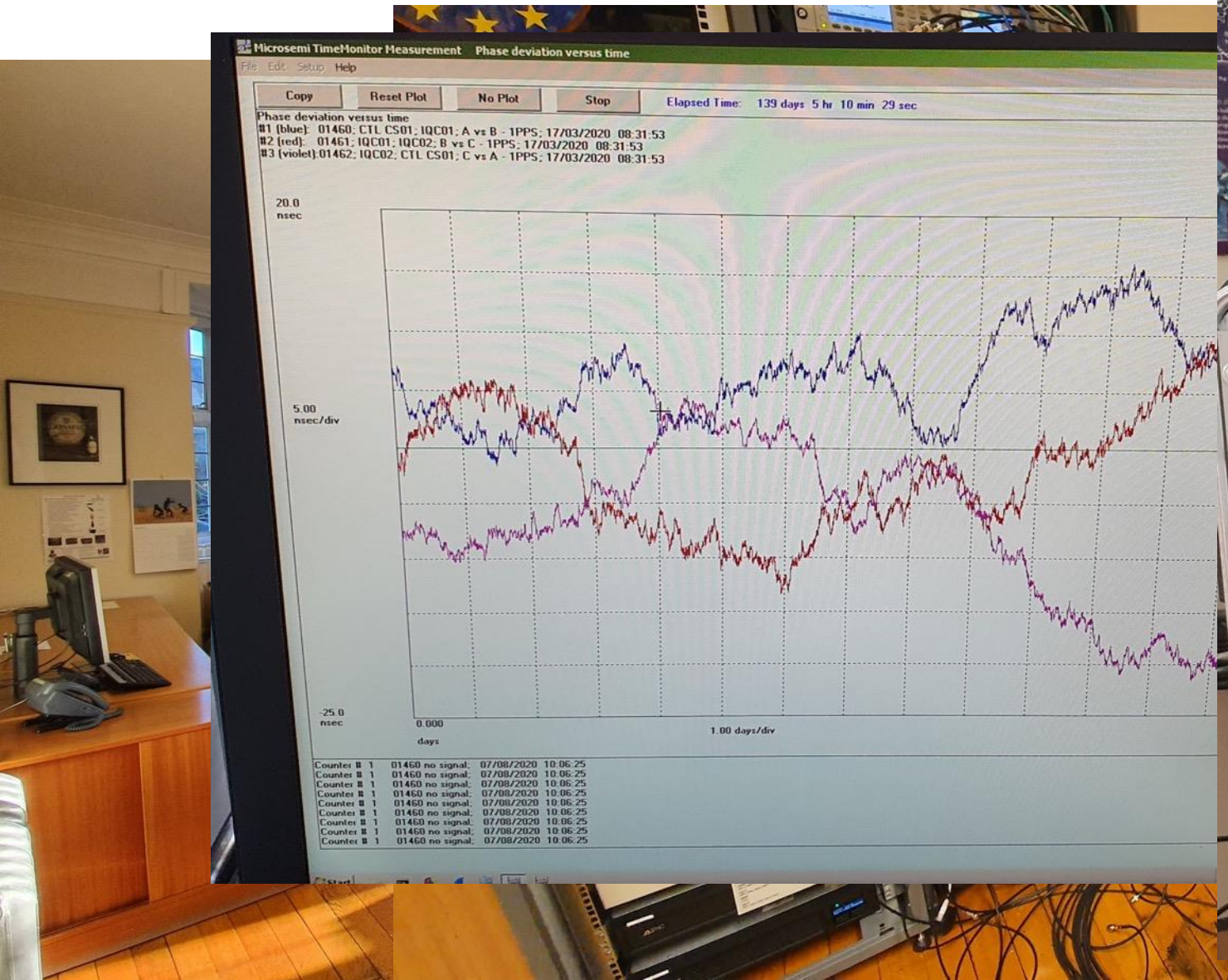
Focusing on these today

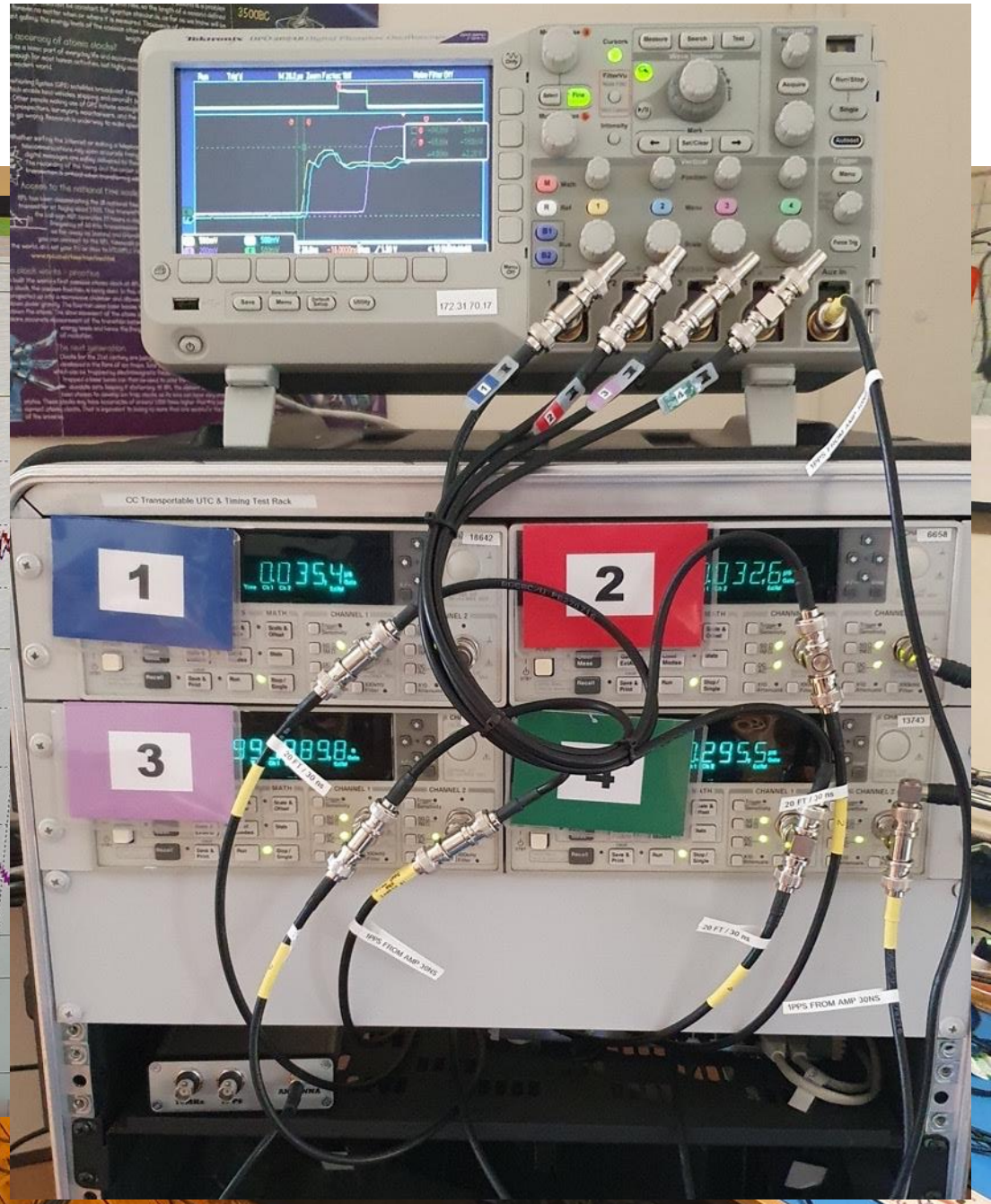
Setup Diagram (simplified)



- GNSS Firewall
  RF input via
  combiner/selector
- Lab Ref
  3 x GNSS/Cs

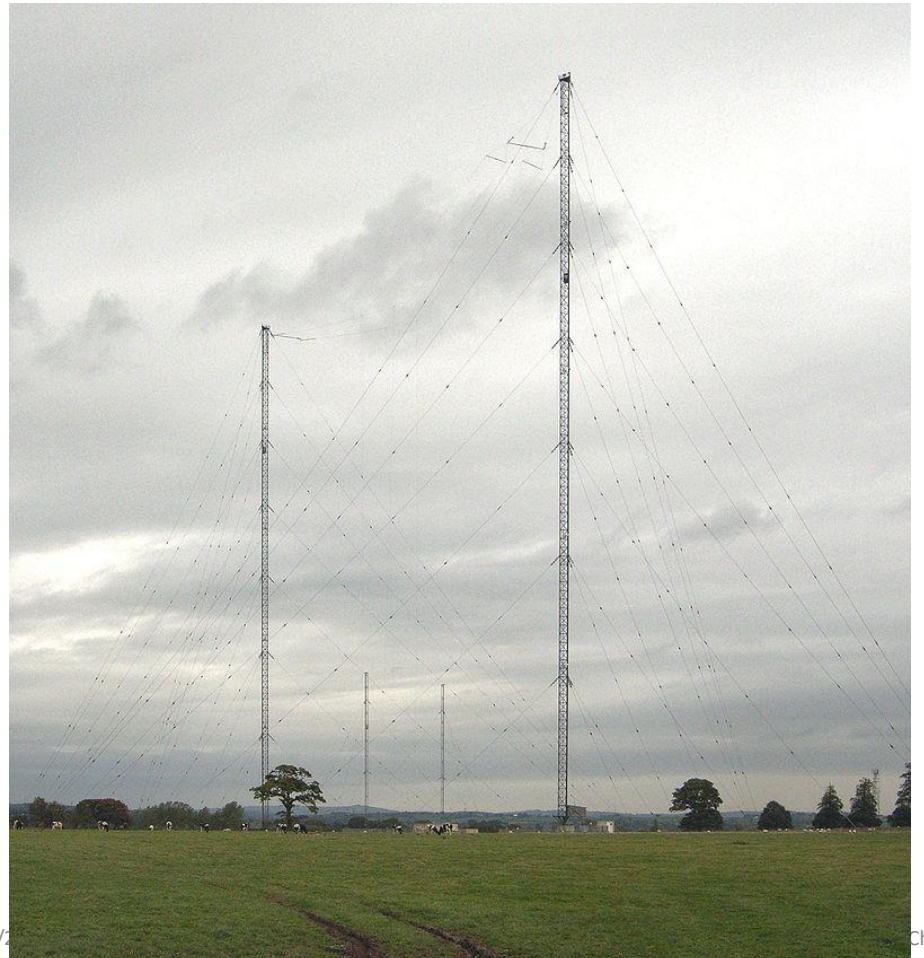
Setup photos





Results – BBC R4 198kHz

- Analogue AM radio signal – 500kW



Droitwich Transmitting Station

From Wikipedia, the free encyclopedia

The **Droitwich transmitting station** is a large broadcasting facility for long-wave and medium-wave transmissions, established in 1934 in the civil parish of Dodderhill, just outside the village of Wychbold, near Droitwich in Worcestershire, England (grid reference SO929663). The site is the location of the British Broadcasting Corporation's most powerful long-wave transmitter, which together with the two Scottish long-wave transmitters at Burghead and Westerglen forms a network broadcasting on the same frequency. The masts can be seen to the east from the M5 motorway, between Droitwich and Bromsgrove, as well as to the west from the Herefordshire/Worcestershire border. At night, the two sets of aircraft warning lights are visible from a long distance. Due to the bright red lights illuminated at night, some locals have renamed the site "the devil horns of Wychbold". The station is owned and operated by Arqiva.

Contents [hide]

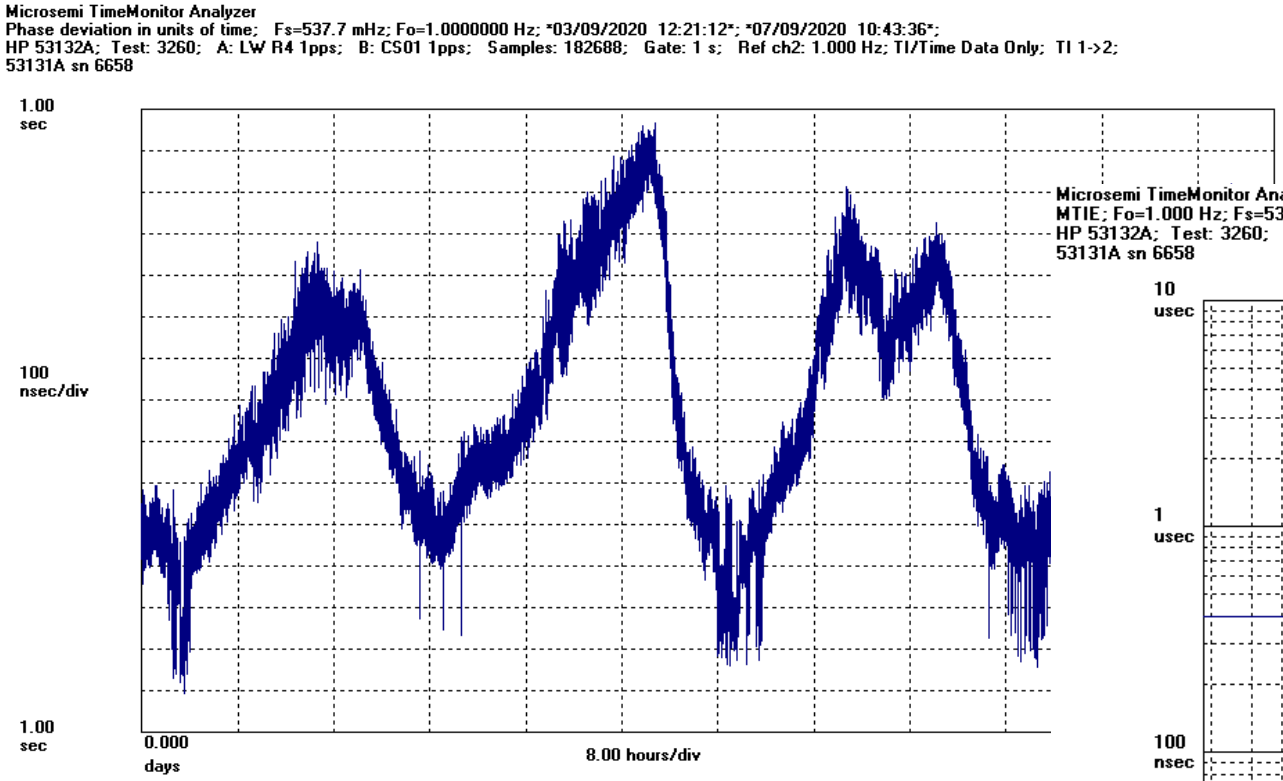
1 Technical specifications
2 Transmissions
3 Reception
4 Services available
5 See also
6 References
7 External links

Technical specifications [edit]

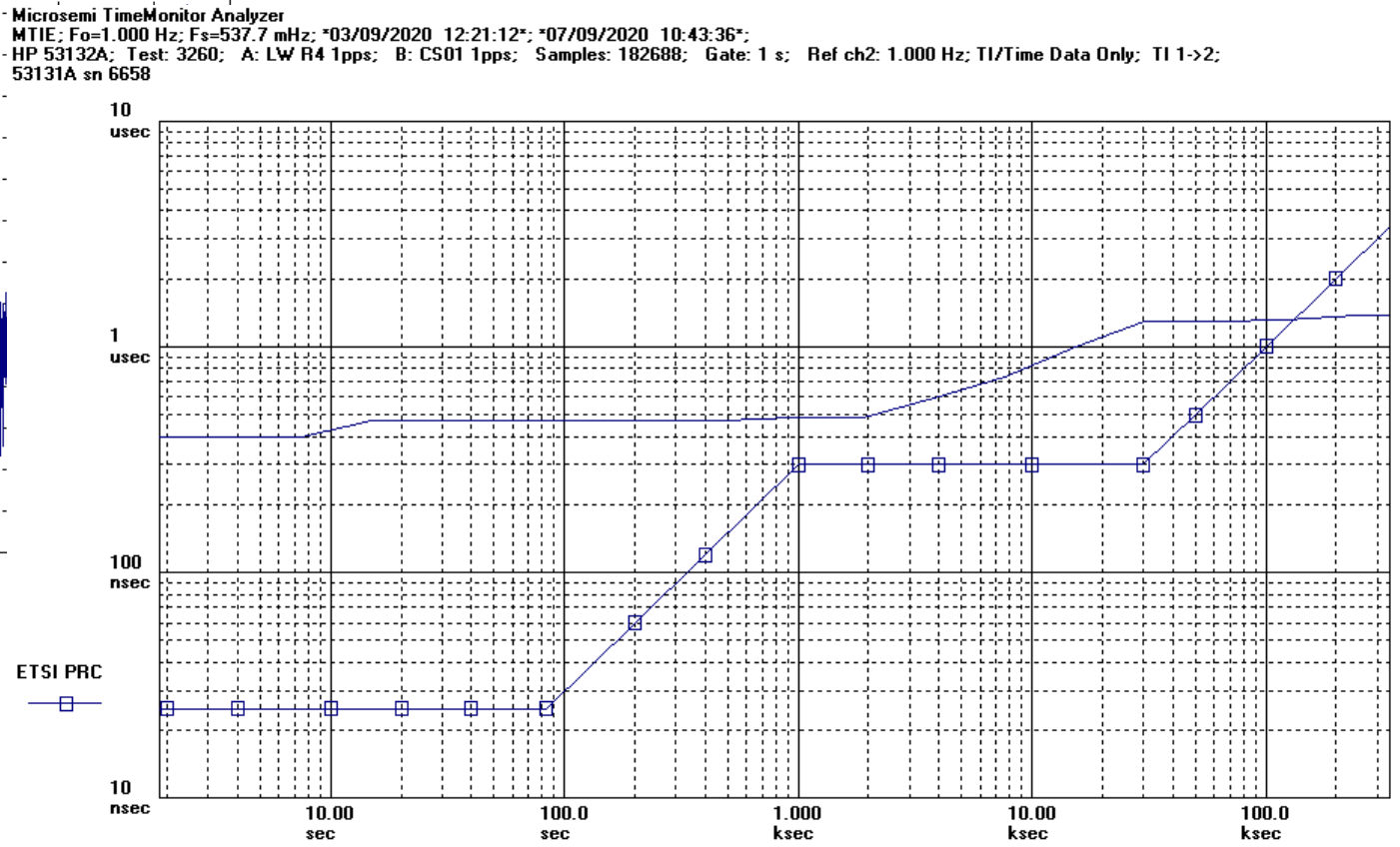
The long-wave frequency used was 200 kilohertz (frequently referred to by the wavelength, 1,500 metres) until 1 February 1988[1] when it was changed to 198 kilohertz, and the power is currently 500 kilowatts. The carrier frequency is controlled by a rubidium atomic frequency standard in the transmitter building, enabling the transmission to be used as an off-air frequency standard. For long-wave, a T-aerial is used, which is suspended between two 213-metre-high (700 ft) guyed steel lattice radio masts, which stand 180 metres (590 ft) apart from each other. There are also two guyed mast radiators at the site. The northerly mast is actually the transmitting antenna whilst the southern mast is a passive reflector causing the rf signal to form a cardioid pattern tending in a NE direction so as not to interfere with the similar set up in Bristol. The smaller mast system transmits digital radio signals. The main large system is used for transmitting AM medium-wave radio programmes on 693 kilohertz, 1053 kilohertz and 1215 kilohertz.

Results – BBC R4 198kHz

TIE = ±800ns wrt UTC



MTIE = 1.6µs



Results - LoRa

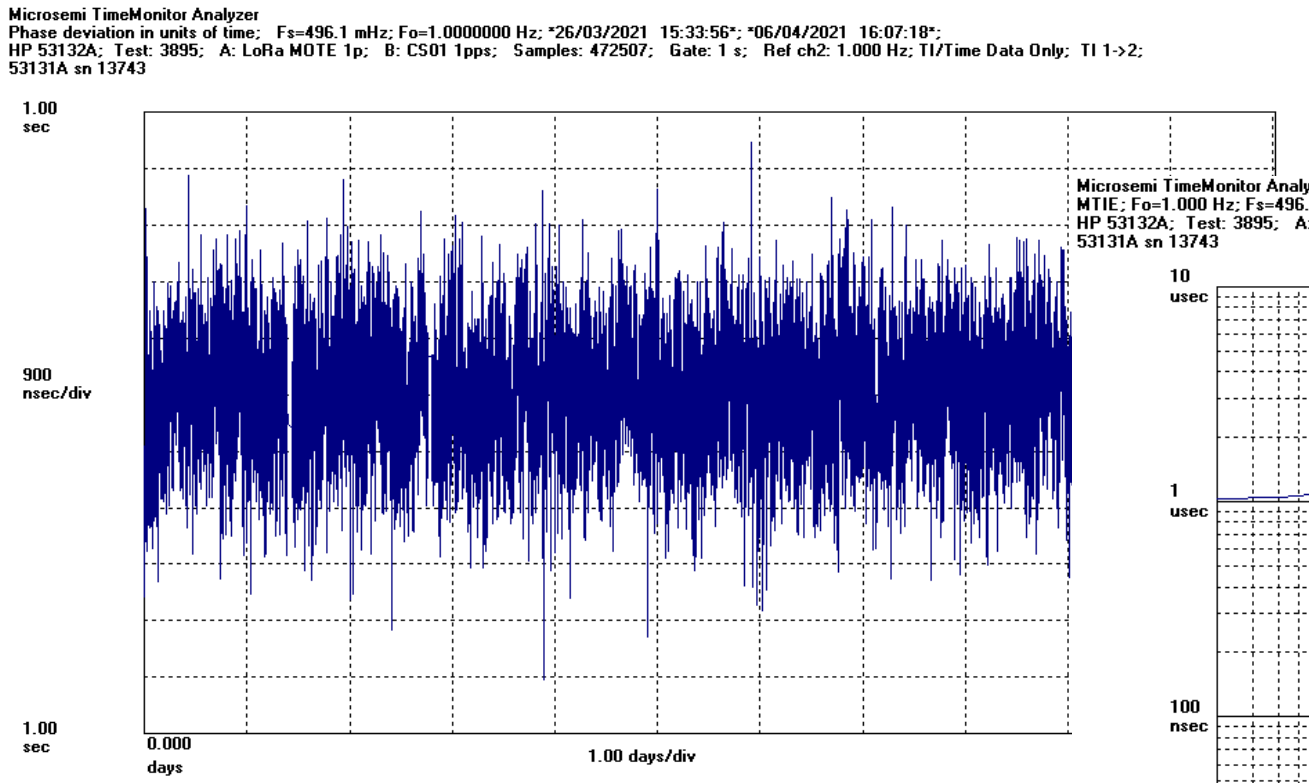
- Gateway – 1PPS in

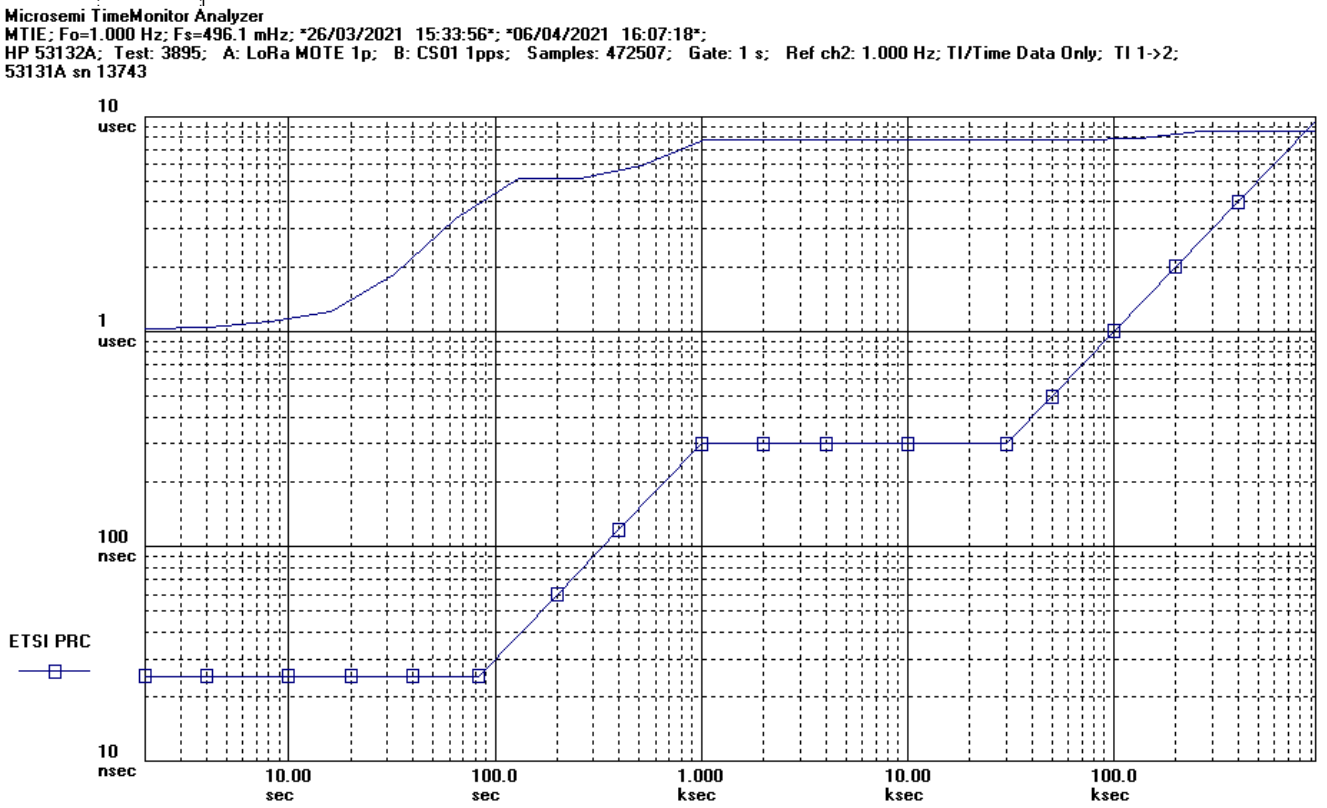
- Mote – 1PPS out

Results - LoRa

TIE = ±4.2µs wrt UTC

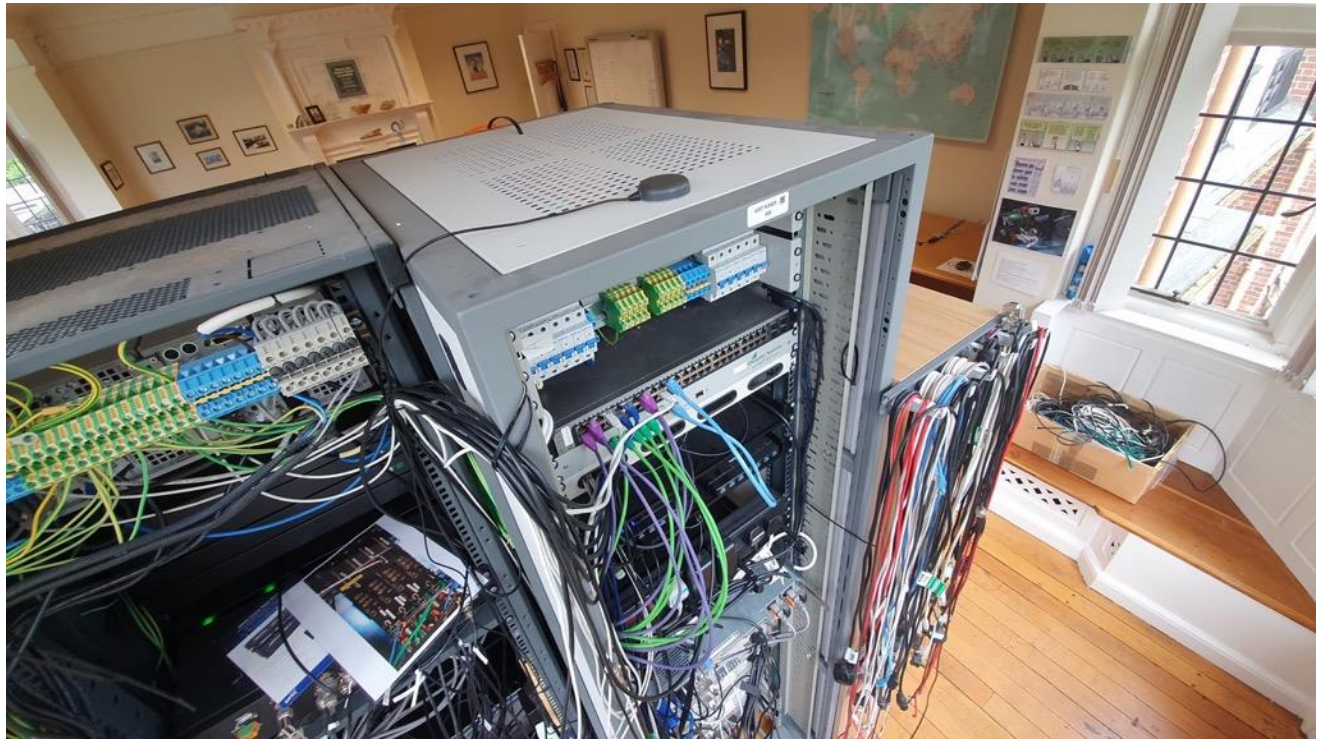
MTIE = 8.5µs

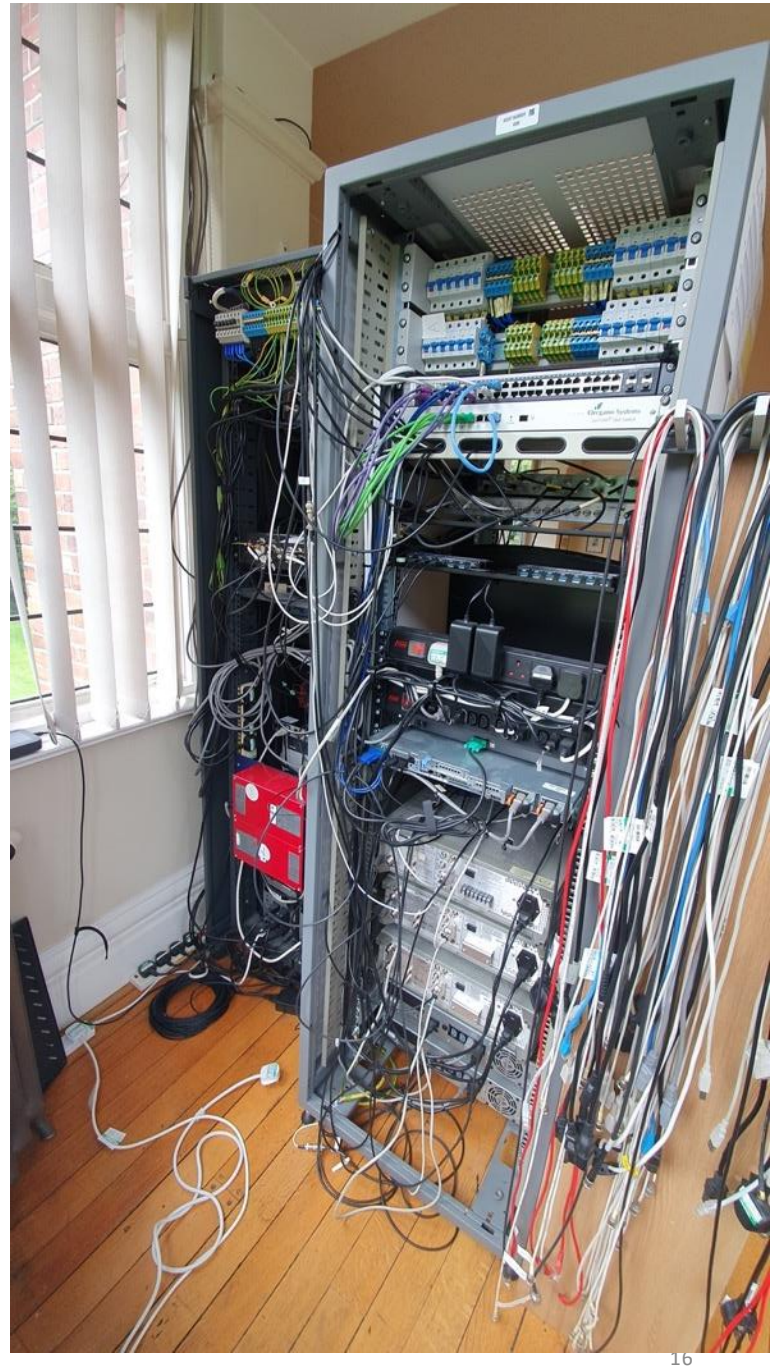




Results - STL

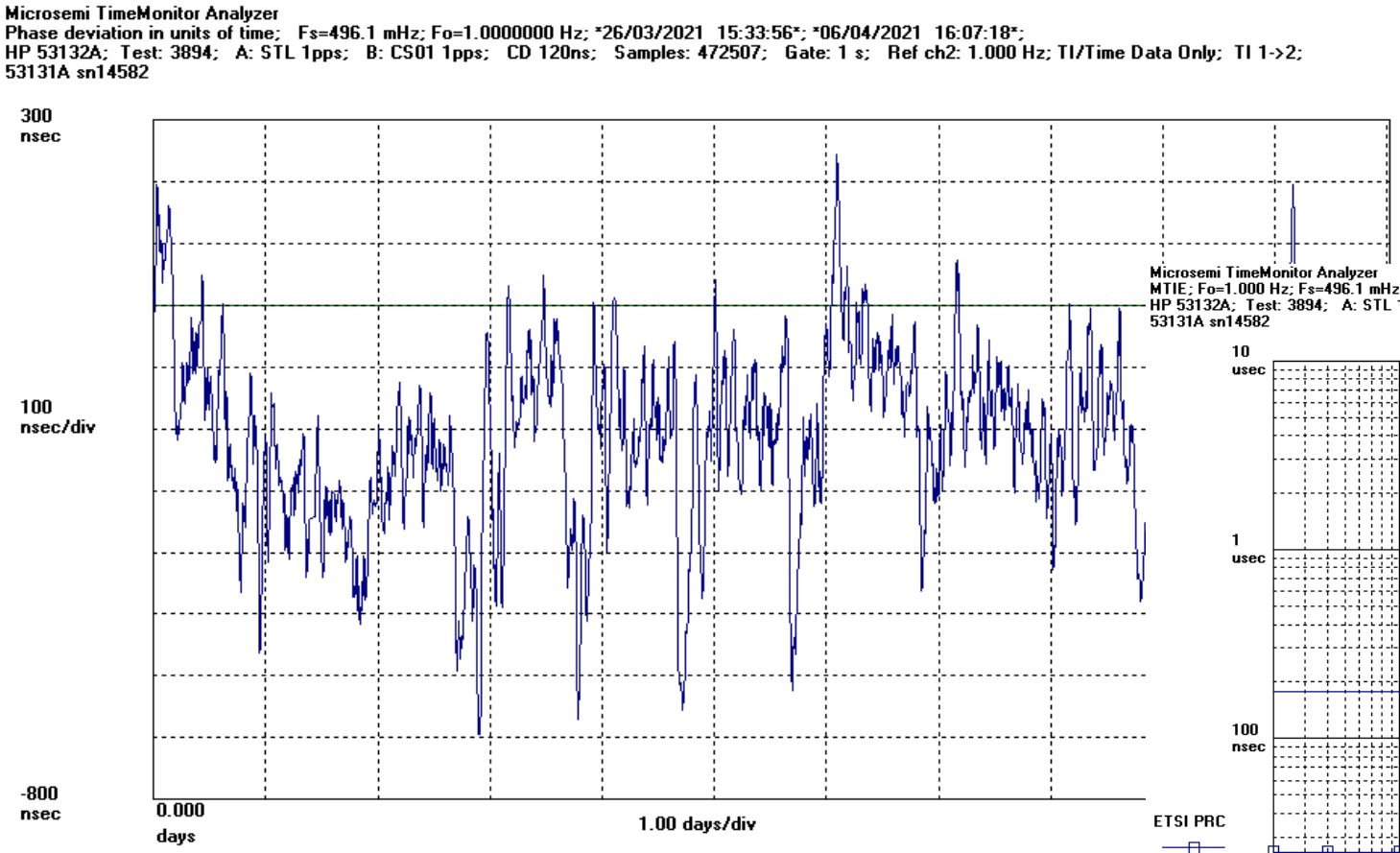
- Global coverage - 66 LEO satellites and traceable to UTC
- Indoor antenna, mounted “as high as possible within the room”
- Iridium satellites perform beamforming to (licensed) receivers
- 1000x (30dB) signal strength than typical GNSS, encrypted



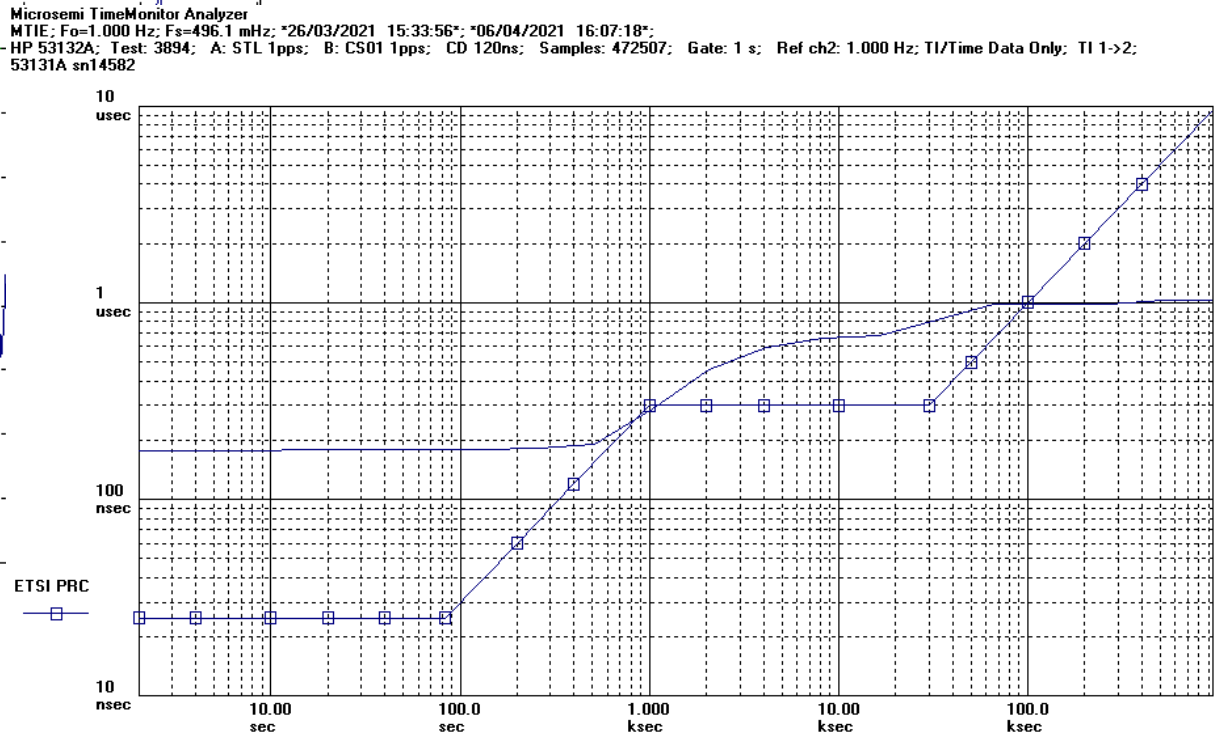


Results - STL

TIE = ±600ns wrt UTC

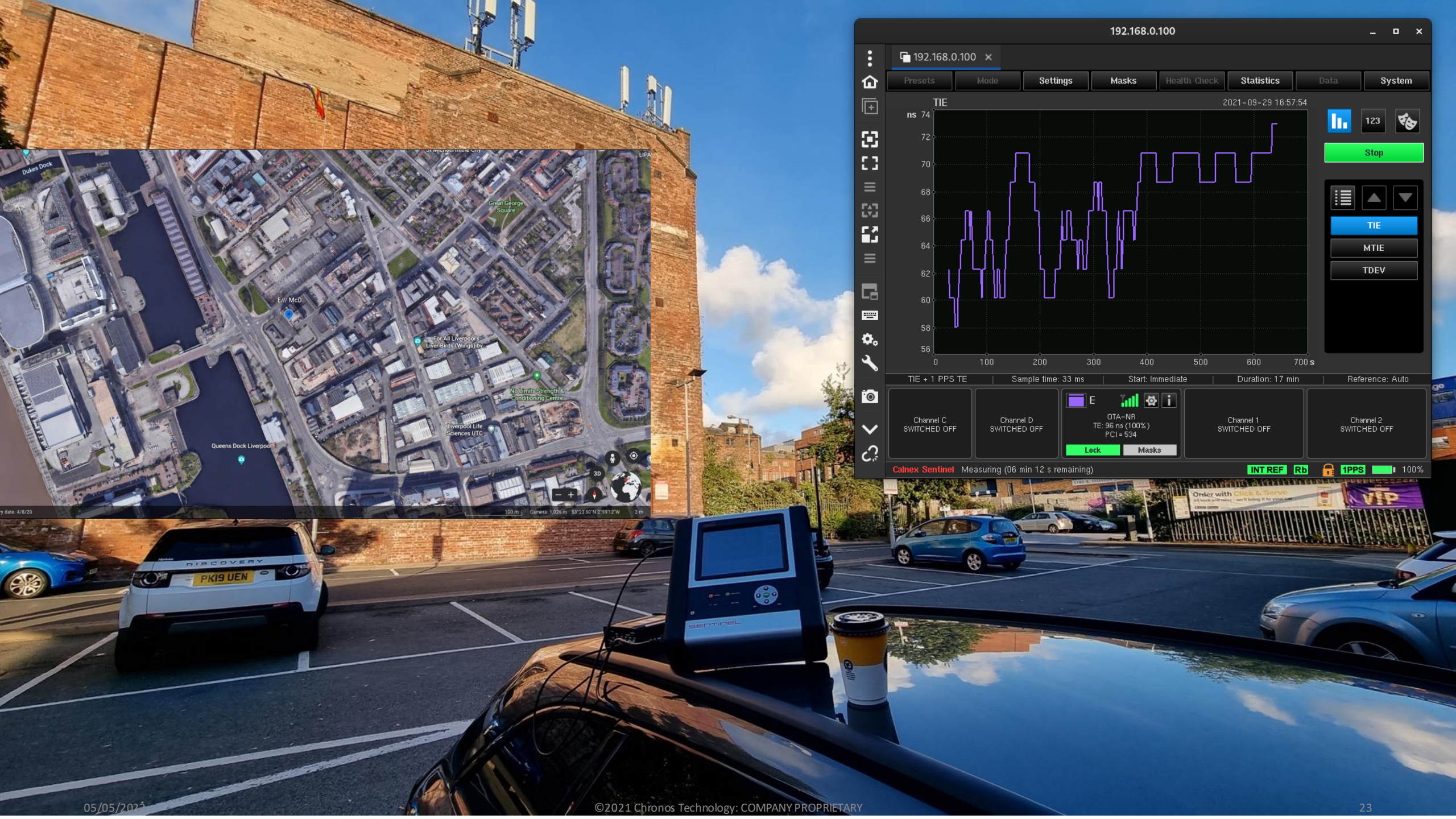


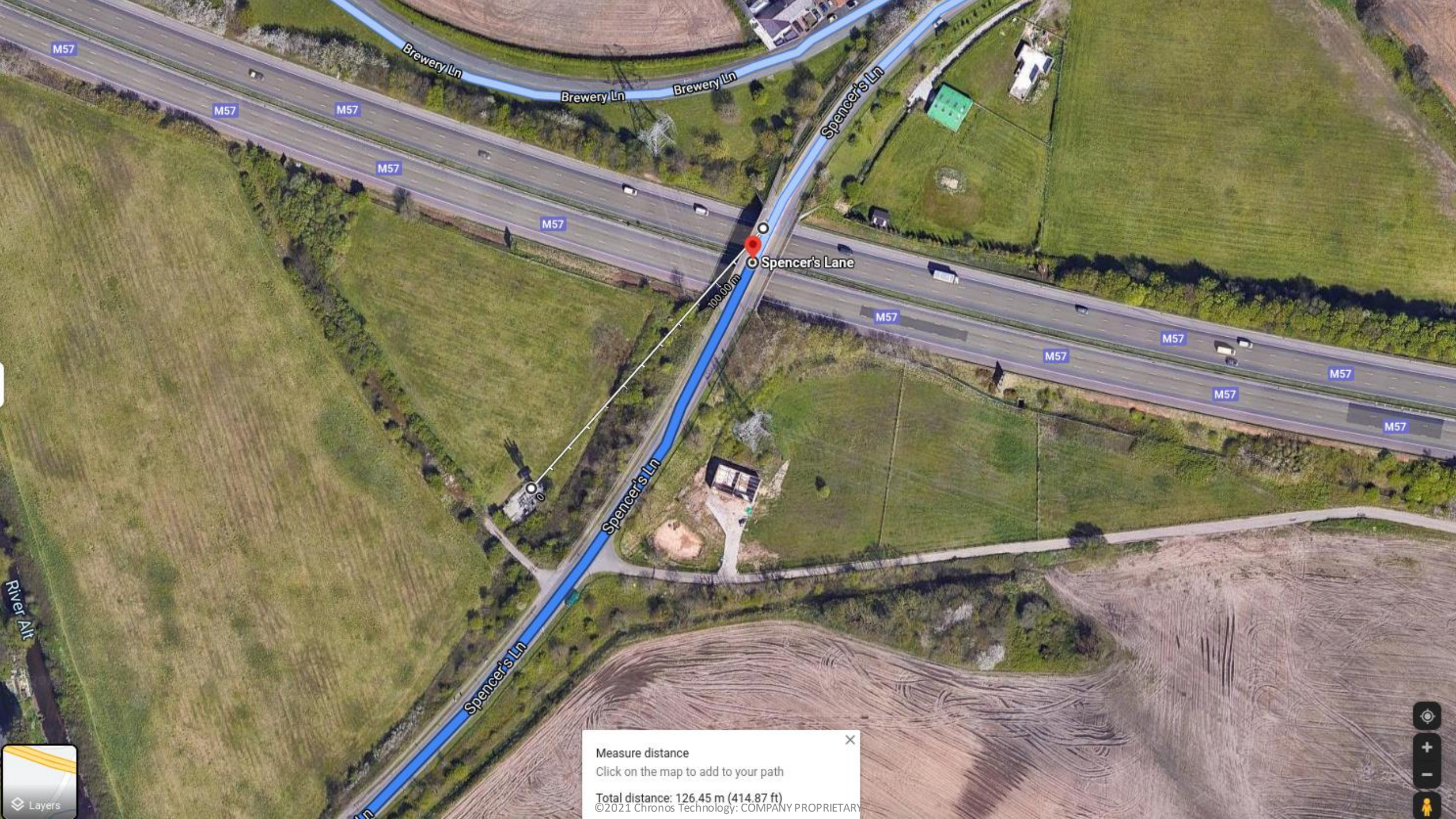
MTIE = 1.0µs



Results - 5G

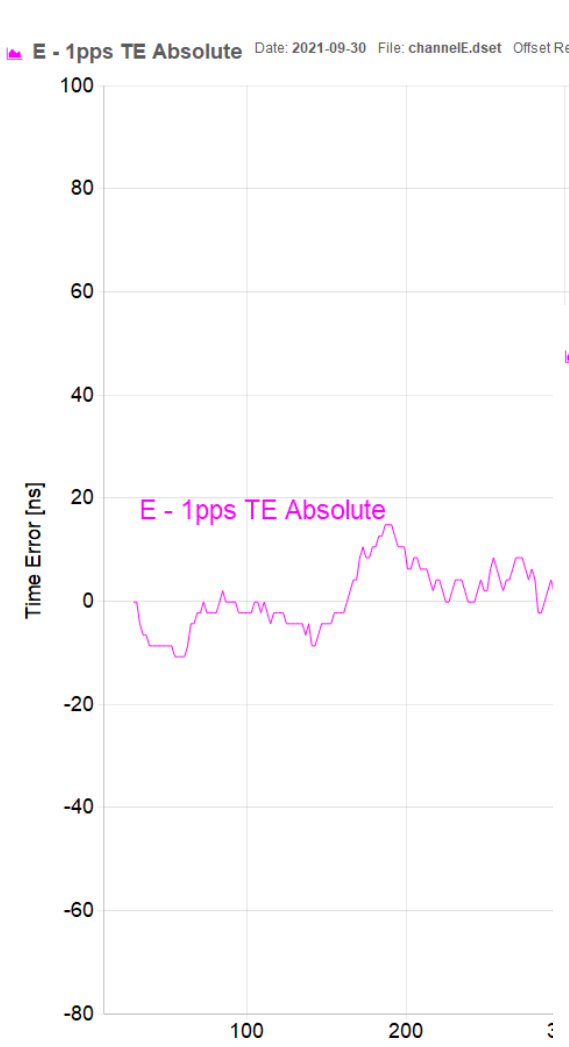
- Portable 5G OTA tester Sep 2021, Liverpool UK
- FriEEndly 5G operator
- Stand-alone GNSS 1PPS reference + estimate of propagation delay

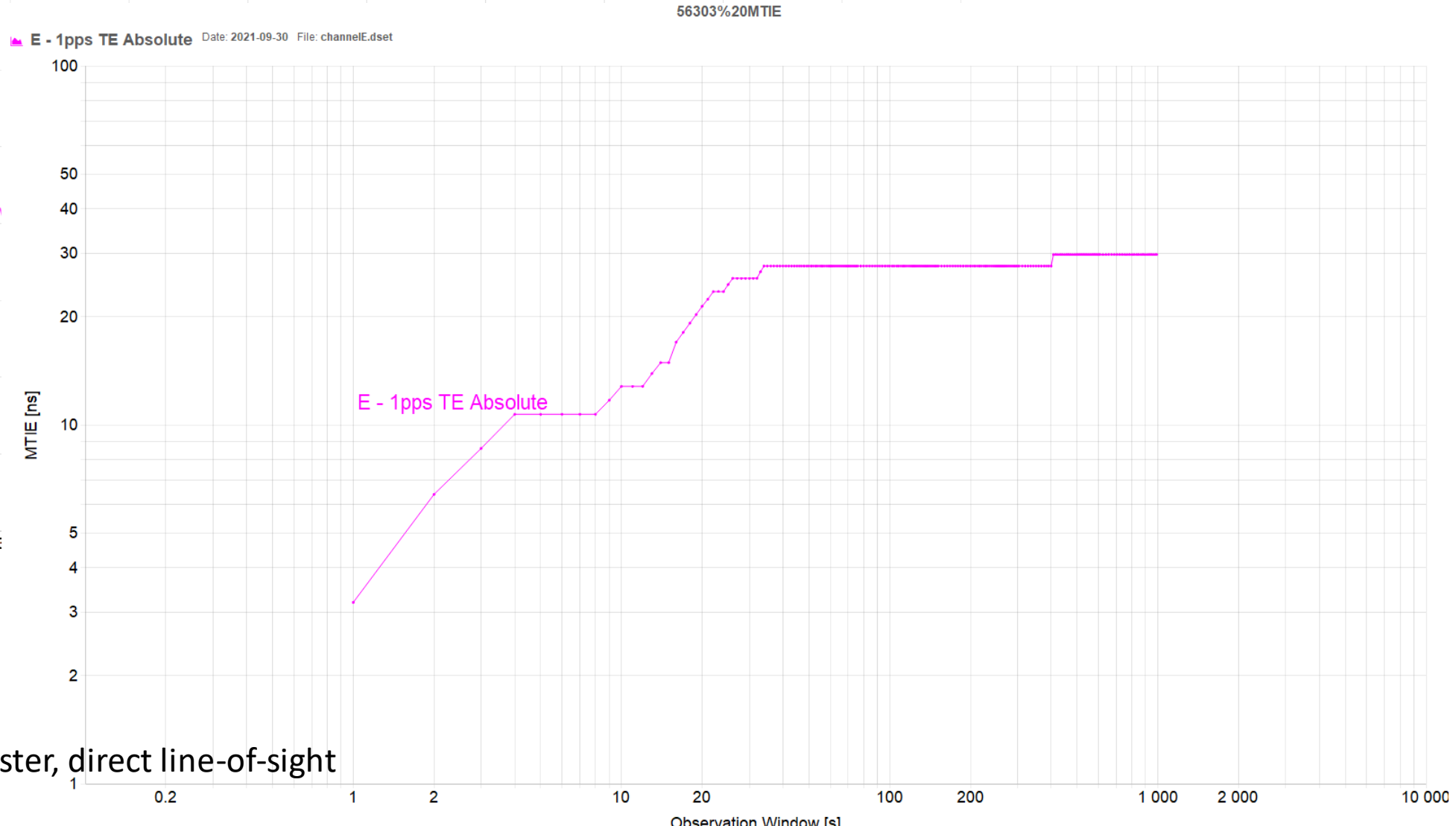




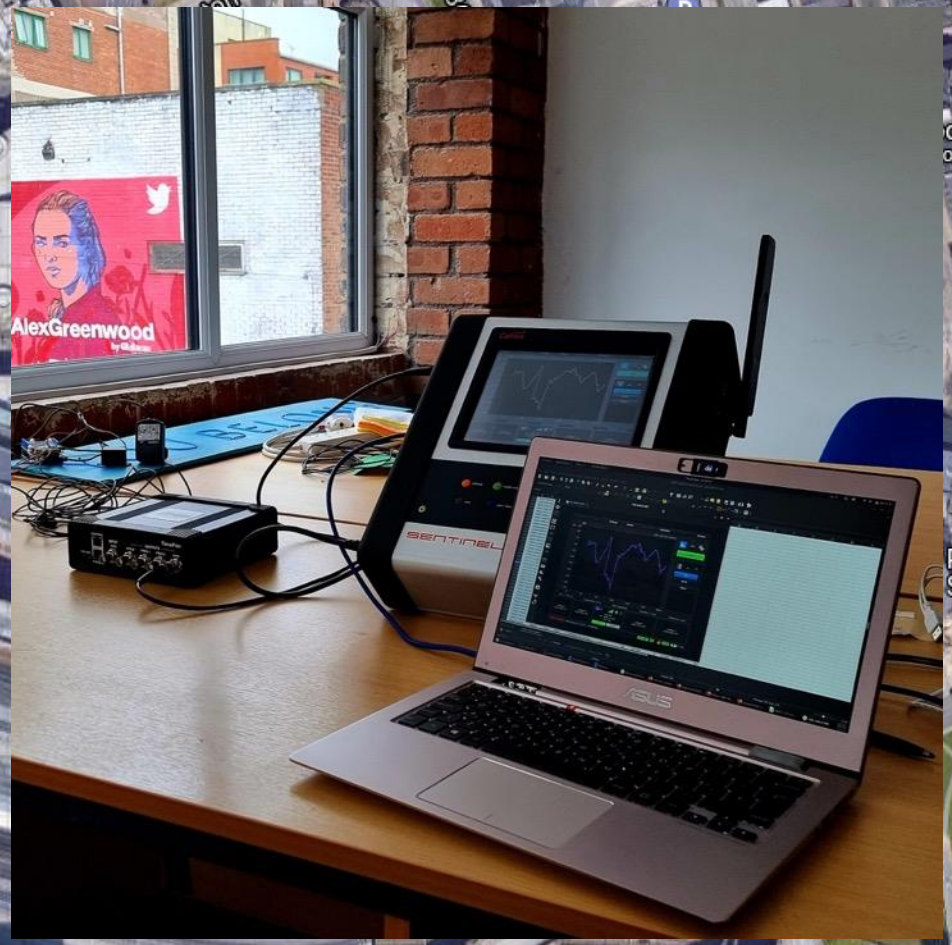
Results – 5G

- Base-station uses local GNSS reference
- 5G basically a proxy for GNSS





Approx. 30m antenna to tester, direct line-of-sight

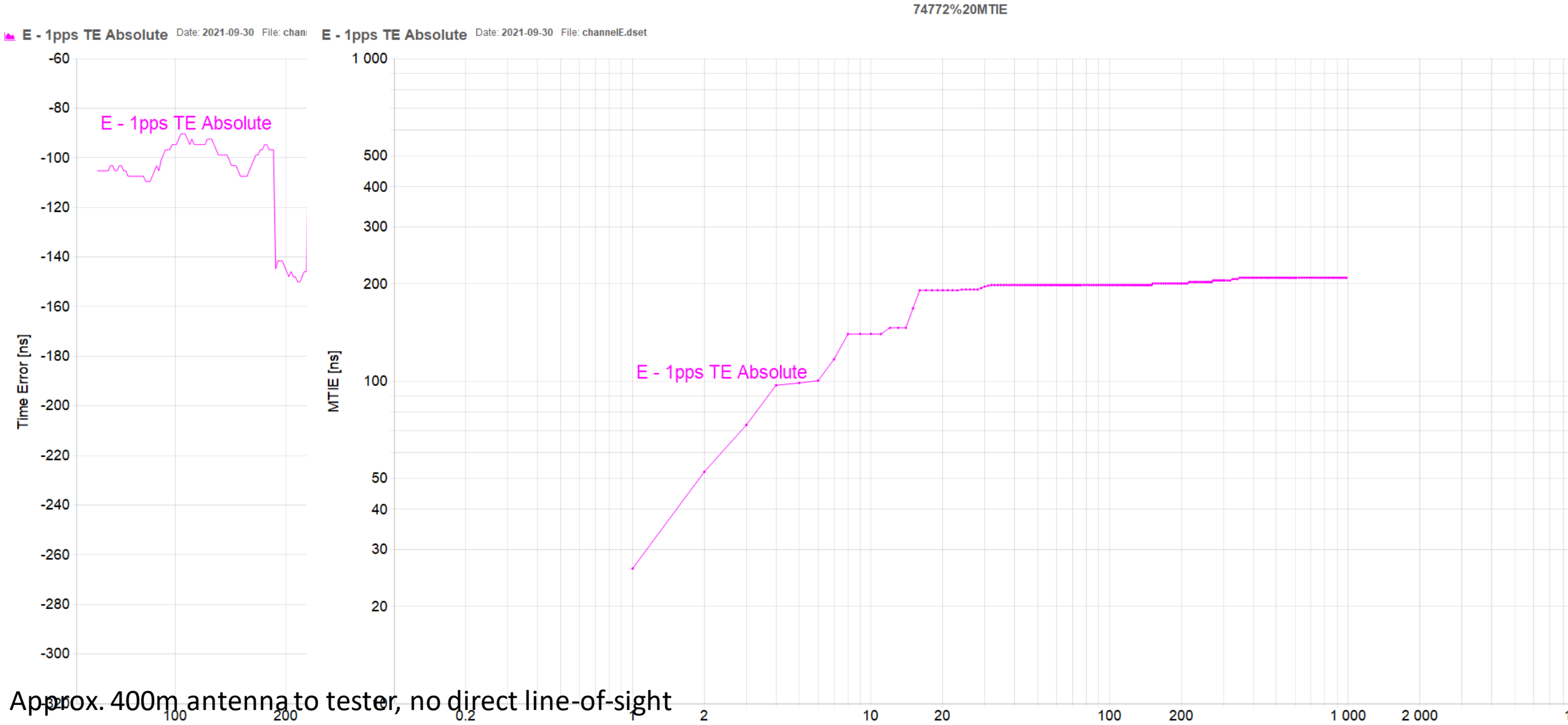


Measure distance

Click on the map to add to your path

Total distance: 404.42 m (1,326.85 ft)

Results - 5G - indoors



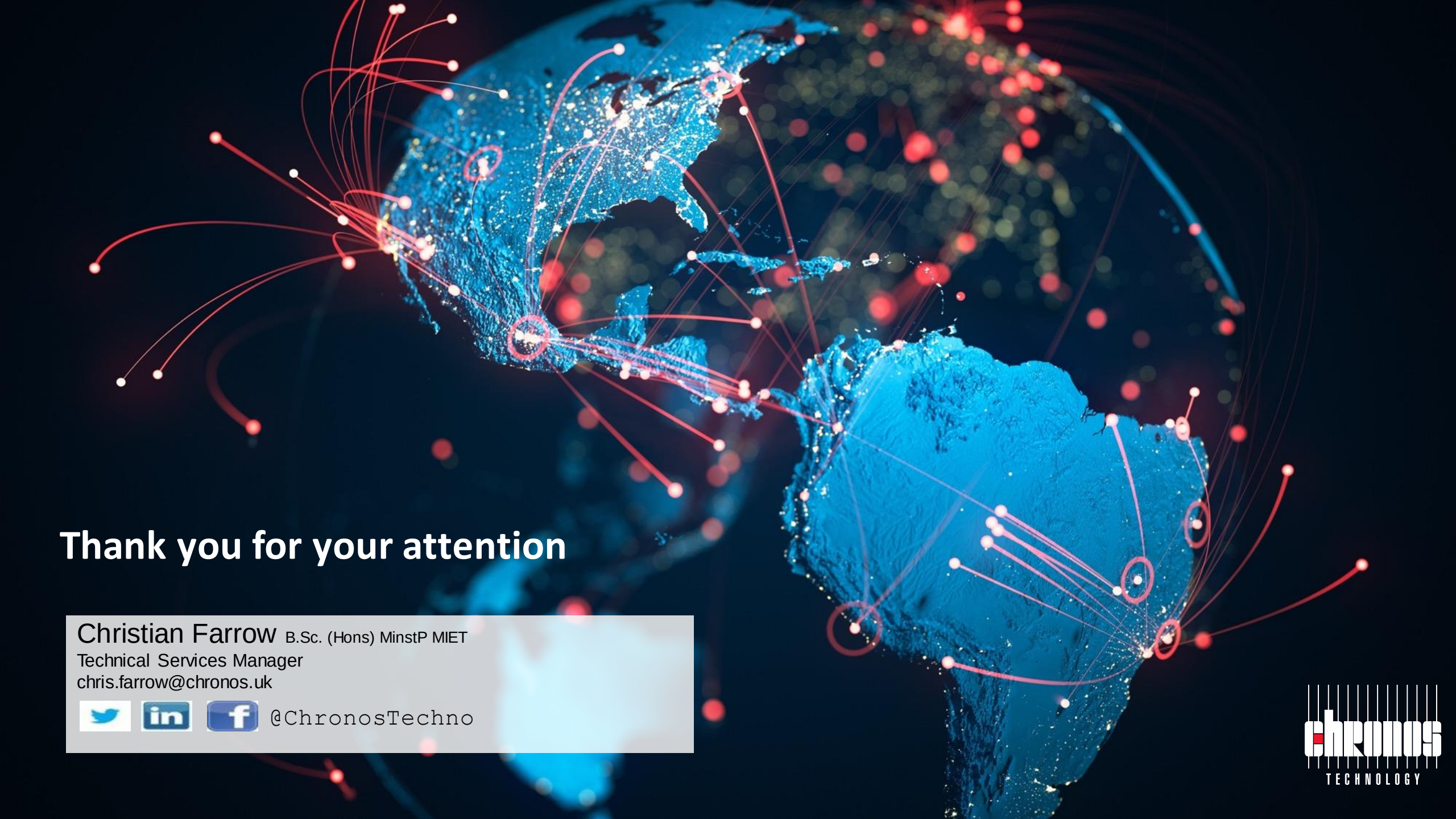
Approx. 400m antenna to tester, no direct line-of-sight

Conclusions

- BBC R4 – prototype receiver,
  transmitter upgrade/re-config?
- STL performed as expected

} ***Capable of delivering ~1µs***

- LoRa - OK for applications with lower accuracy reqs (or LoRaSync?)
- 5G shows promise but for ultimate accuracy needs calibration for propagation delay (i.e. needs Rx & TX position knowledge)
- Future research work looking at combining “Signals of Opportunity”
- (GNSS-MCMF/eLORAN/CSAC results in the slide deck)
- And… *on a personal level this work helped me get through the UK Lockdowns 2020/1*



Thank you for your attention

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For reference – hidden slides follow

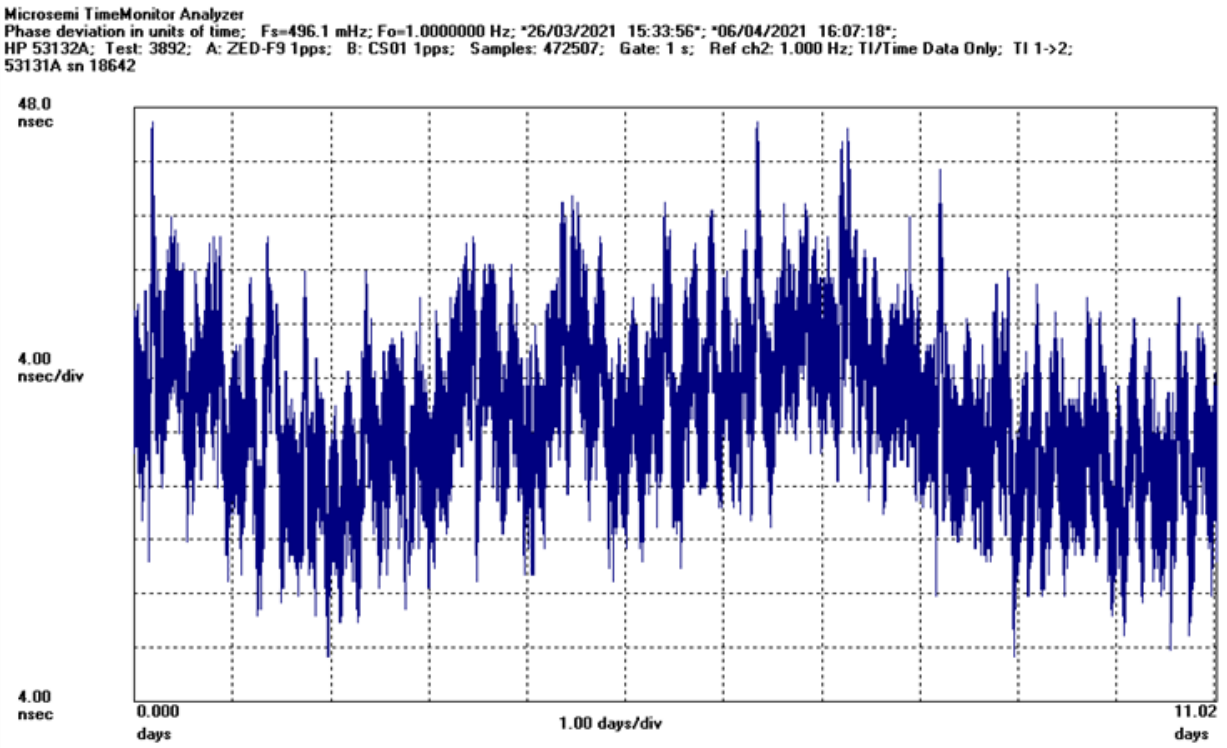
chronos TECHNOLOGY

Setup

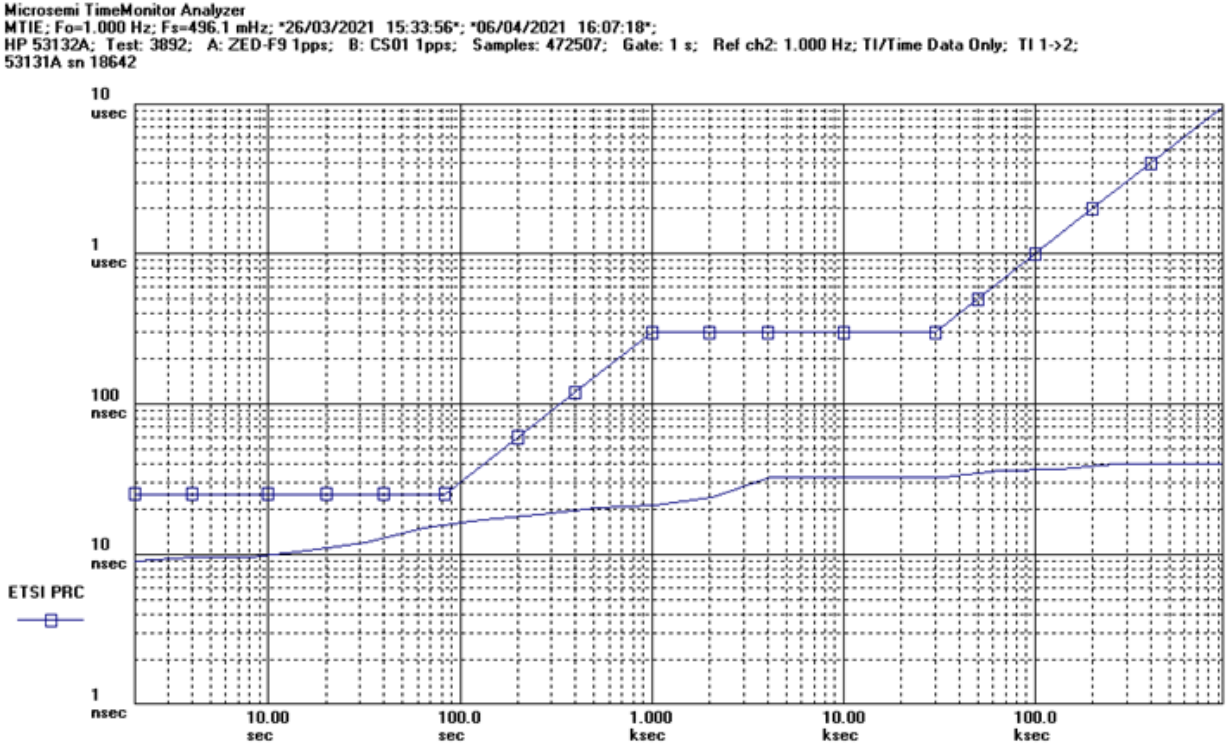
- Live sky + (remote control) jammer via RF combiner
- Pre-recorded jamming scenarios (LabSat)
- “Constellation errors” SVN23 scenario (Spirent)
- 2 x (synchronised) Simulators + scenarios (Syntony) – basic/intermediate/advanced spoofer
- GNSS FireWall (Microchip) – 10MHz/1PPS from alternate source → (simulated o/p) → test receiver ublox M8-T

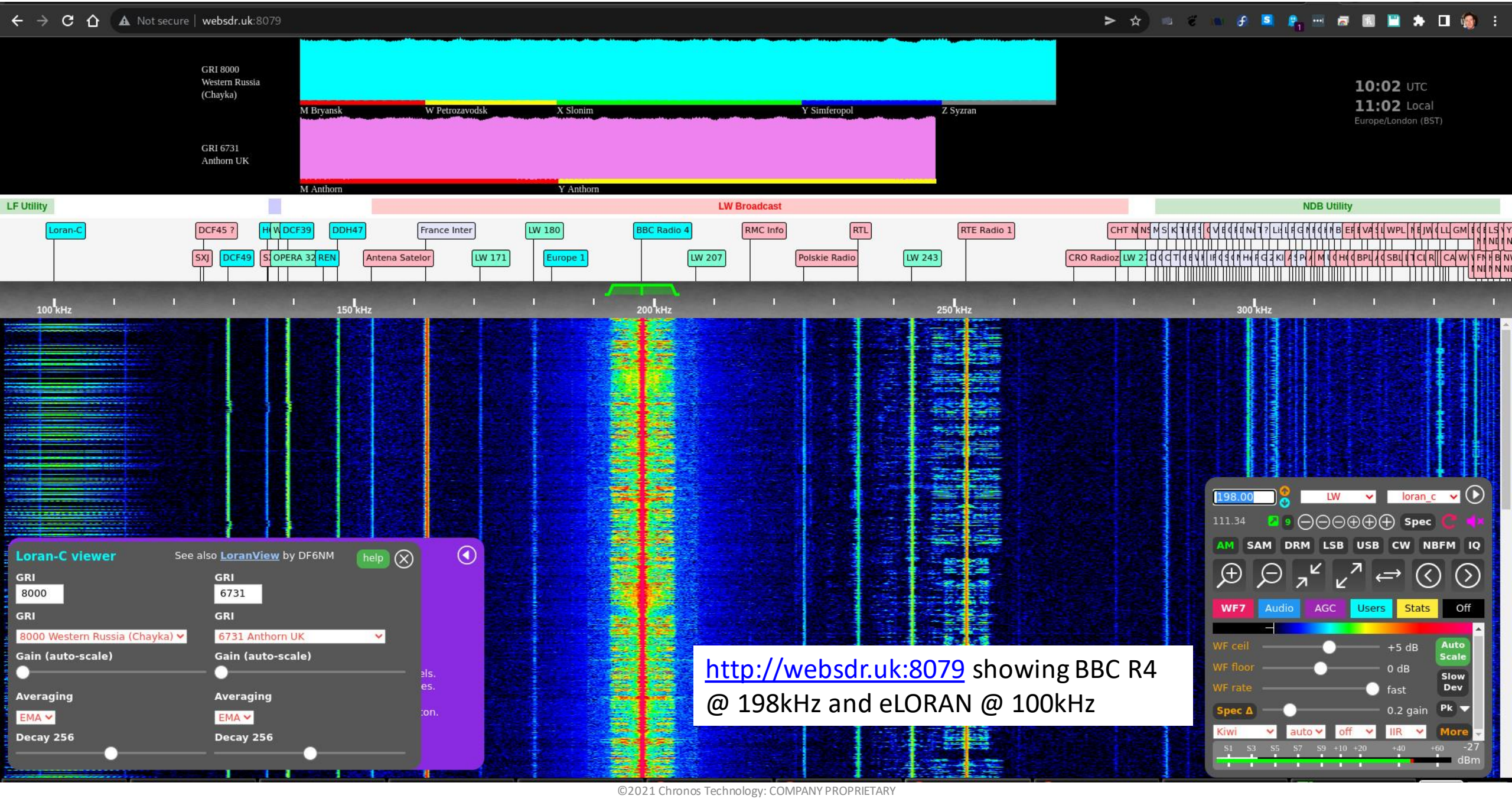
Results MCMF-GNSS

TIE = ±16ns wrt UTC



MTIE = 30ns





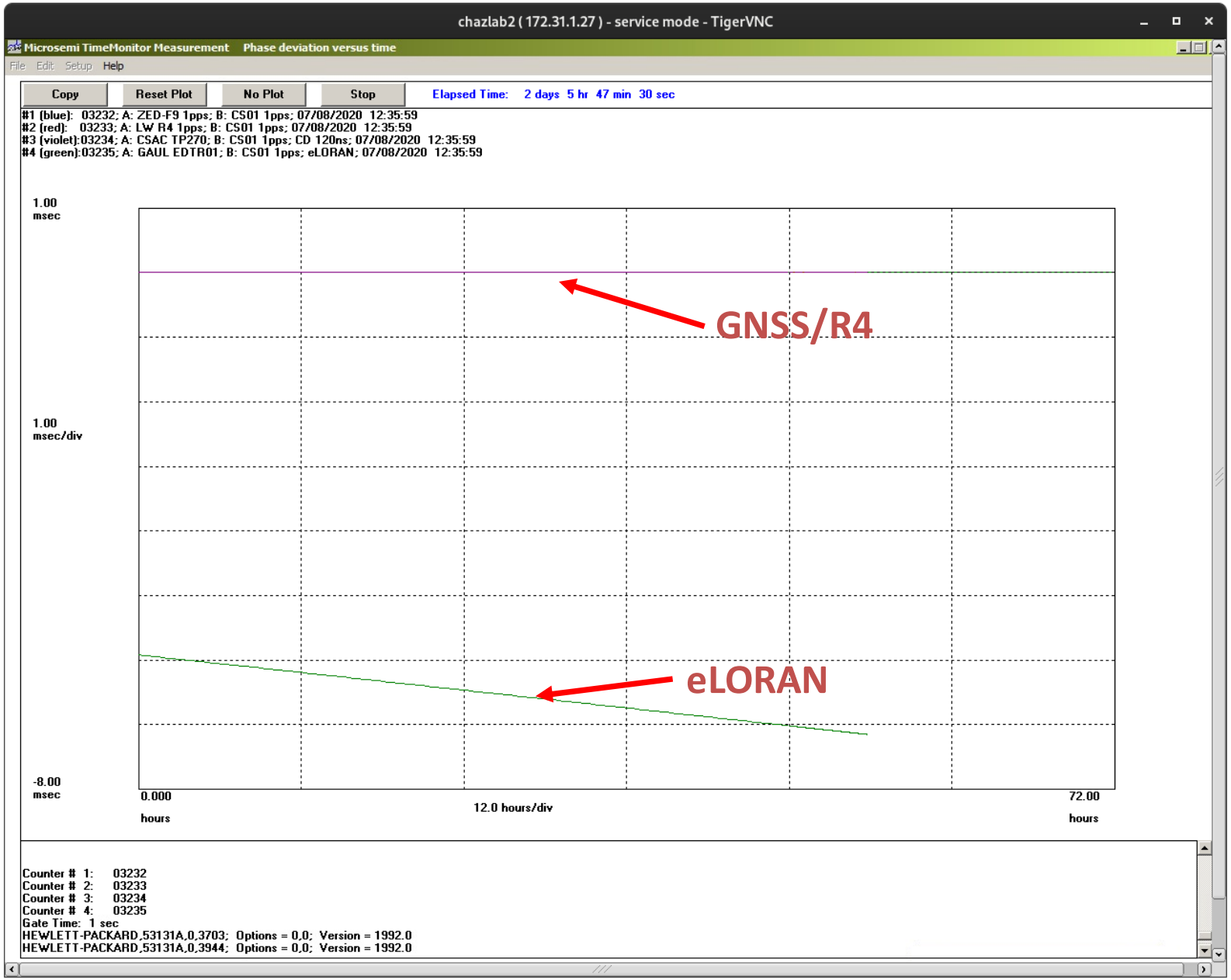
http://websdr.uk:8079 showing BBC R4 @ 198kHz and eLORAN @ 100kHz

Results – eLORAN

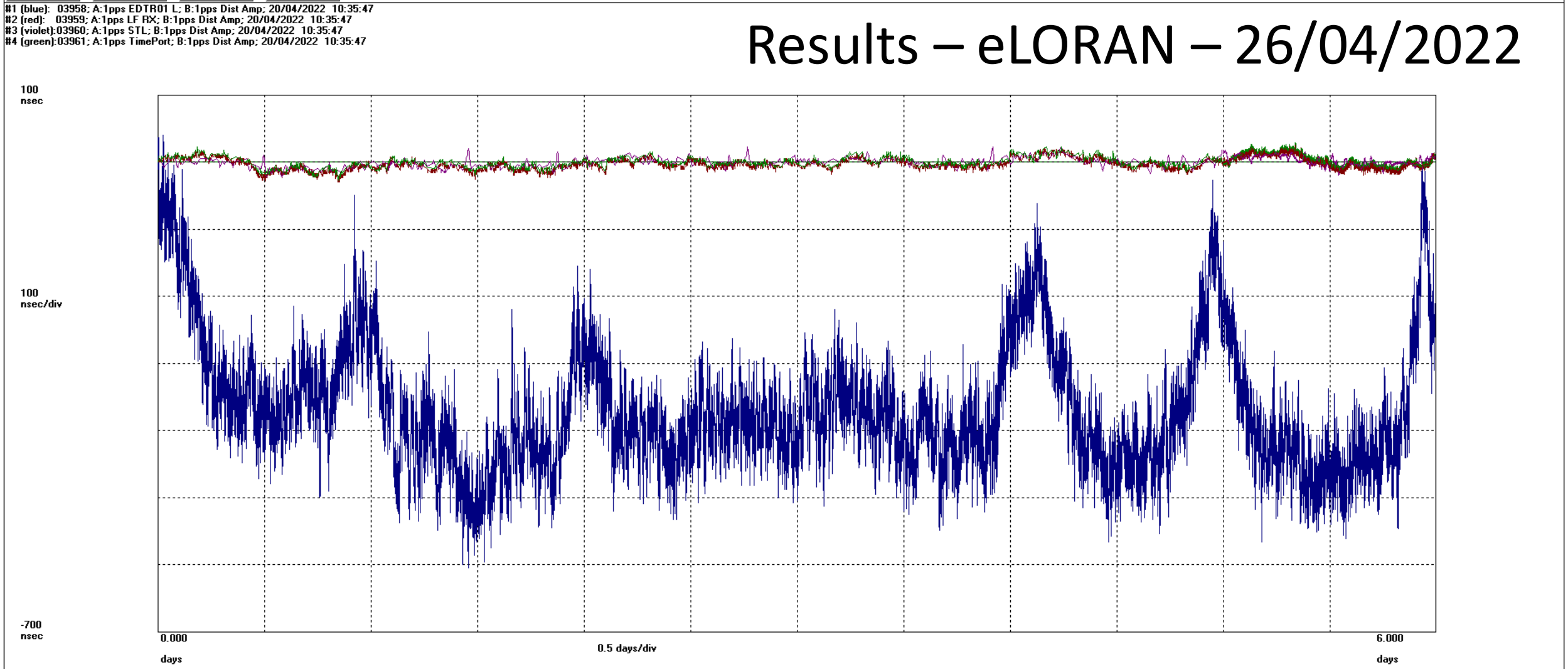
- Only eLORAN transmitter “working” in Europe…!
  (*“research” status*)

  in 2020:
  6-7ms offset + 6.7ppb

  Cs reference had failed



Results – eLORAN – 26/04/2022



eLORAN (blue trace) ~600ns p-p error over 6 days
(no ASF compensation on receiver)
other traces (red/violet/green) all GNSS-traceable

Results - CSAC

- Performed roughly as expected to Datasheet Specifications

  approx. 2µs/day