



HET MEEST VEELZIJDIGE NETWERK

OG-GPS



# COMPANY INFORMATION

06-GPS BV

NL Sliedrecht

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# COMPANY INFORMATION 06-GPS

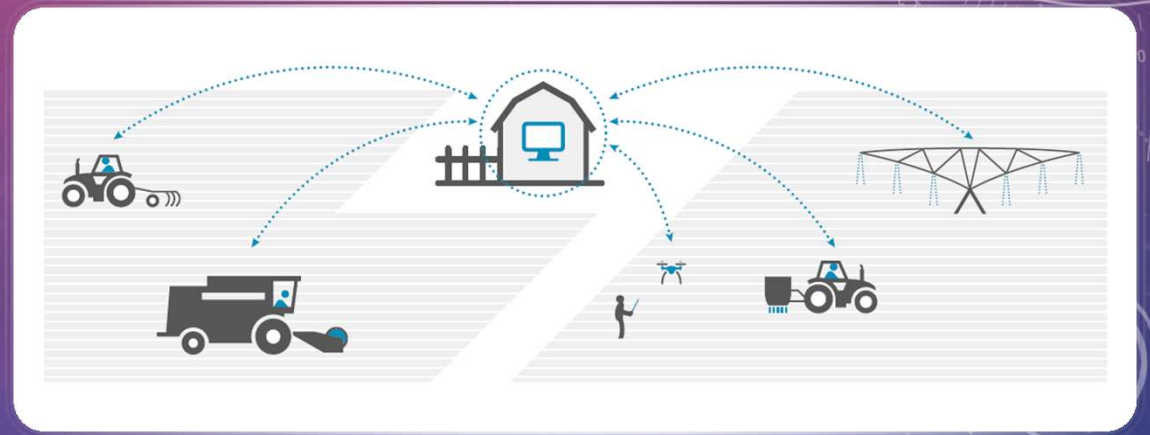
- Independent, commercial provider of GNSS-data
- 20 years of expertise in Network GNSS-RTK
- Market leader of Network RTK in the Netherlands
- 5 employees full time, 6 employees part time
- Part of group of companies in surveying and engineering with over 200 employees in total



# COMPANY INFORMATION 06-GPS

## Thousands of registered users:

- Governments (national, local, communities)
- Surveying and engineering companies
- Contractors (roads, railways, underground infrastructure)
- Energy companies
- Archeologists, police, schools, universities
- Farmers, Drones, Automotive, etc.





## 4 GNSS CONSTELLATIONS



### GPS

6 Orbital planes  
24 Satellite + Spare  
55° Inclination Angle  
Altitude 20,200 km



### Galileo

3 Orbital planes  
27 Satellite + 3 Spares  
56° Inclination Angle  
Altitude 23,616 km



### GLONASS

3 Orbital planes  
21 Satellite + 3 Spares  
64.8° Inclination Angle  
Altitude 19,100 km



### BeiDou

6 Orbital planes  
35 Satellite + 3 GEO + 27 MEO + 3 IGSO  
55° Inclination Angle  
Altitude 38,300 km, 21,500 km

## COMPANY INFORMATION 06-GPS

Benelux coverage

Full support of GPS, GLONASS, Galileo, Beidou

Delivery RTK over NTRIP (internet) using RTCM 3 format

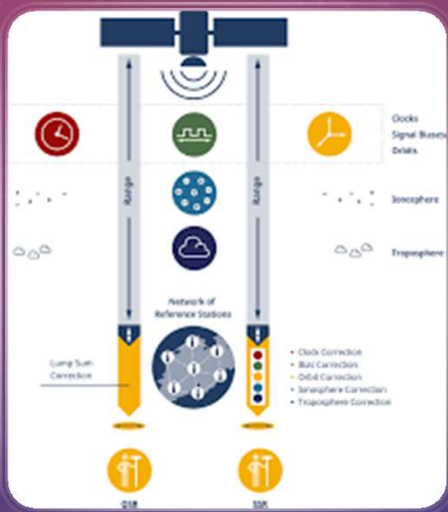
Over 10 years of cooperation with (among others):

LTO Nederland, the Netherlands Agricultural and Horticultural Association (>35000 members).

Bouwend Nederland, the employers' organization in the construction and infrastructure industries (4300 members).

Extensive relations with, and knowledge of other networks within Europe.

Planned upgrade to PPP-RTK (SSR: Compact, SSR-Z / SPARTN / IGS)





# QUALITY 06-GPS

## Certifications:

TüV SüD / Navcert

Accuracy 2cm (95%)

Availability (99%)

Competence and service



TüV SüD / Navcert

dynamic acc. 2cm (95%)

Suited for Precise Farming

Suited for Guidance Systems

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  - Discovering of radio interference
  - Finding the source of interference
  - Contact with interference source





# CASE 1: MOBILE NETWORK PROVIDER

GNSS interference caused by new signals in telecommunicationS



# GNSS-RECEIVERS AT EACH BASE STATION:

Each 06-GPS station has two different receivers on same antenna using an antenna splitter

## Topcon NET-G5



## Septentrio PolaRx5



# DISCOVERING RADIO INTERFERENCE

- Important to know the normal (SNR) values
- Affected Site: Ede
  - Topcon NET-G5 receiver stated to show low SNR at GPS
  - Septentrio PolaRx5 receiver was still showing normal SNR at GPS

Status NET-G5 ID:W1NAJNNOC20

Position Misc SV List Sky Plot Scatter Position In Time Logging

PRN↑	EL	AZ	C/A	L2C	L1P	L2P	L5	TC	SS	
G2	31+	310	40		32	32		63	0	
G3	29-	106	38	38	37	37	40	325	0	
G4	59-	66	39	41	36	37	42	91	0	
G6	62-	254	42	44	41	42	44	91	0	
G7	21+	172	38	35	36	36		24	0	
G9	78+	218	40	42	40	40	42	90	0	
G17	6-	224	34	31	28	28		91	0	
G19	14-	236	37		24	24		90	0	
G22	9-	112	33		19	19		91	0	
G26	9+	50	33	34	27	27	39	19	0	
SN↑	EL	AZ	C/A	L2CA	L1P	L2P	L3	TC	SS	FCN
R1	67-	40	40	41	40	41		36	0	1
R2	36+	274	44	44	44	44		86	0	-4
R8	26-	70	42	42	42	42		35	0	6
R9	10-	12	40	40	39	39		143	0	-2
R10	33+	58	42		42			35	0	-7
R11	21+	122	41	40	41	40		36	0	0
R17	47+	292	41	43	41	43		112	0	4
R18	16+	340	39	40	39	40		26	0	-3
R23	7-	192	39	34	38	34		36	0	3
R24	36-	218	42	43	41	43		212	0	2
PRN↑	EL	AZ	E1	E5a	E5b	E5ab	E6	TC	SS	
E2	18+	60	36	39	38	39	39	64	0	
E7	79-	70	40	43	41	42	42	91	0	
E8	26-	70	39	41	40	41	41	359	0	
E13	5-	170	33	34	33	34	34	91	16	
E20	??	??	38					48	29	
E25	6-	12	34	37	37	37	36	30	0	
E26	45-	208	41	41	39	40	40	91	0	
E30	11+	108	36	38	37	37	38	7	0	
PRN↑	EL	AZ	B1	B1C	B2b	B2a	B3	TC	SS	
C5	13-	122	35		36		38	64	0	
C7	8+	64	34		36		39	15	0	
C9	15-	54	35		37		37	90	0	
C12	14+	330	36		39		40	16	0	
C19	75+	286	41				23	143	0	
C20	49-	86	40				41	304	0	



# COMPARING TOPCON NET-G5 AT VARIOUS SITES:

With interference

Status NET-G5 ID:W1NAJNNOC20

Position Misc SV List Sky Plot Scatter Position In Time Logging

PRN↑	EL	AZ	C/A	L2C	L1P	L2P	L5	TC	SS	
G1	6-	150	32	32	26	27	38	8	0	
G2	17+	316	38		25	25		8	0	
G3	44-	94	40	41	40	40	43	289	0	
G4	74-	90	40	42	38	38	42	27	0	
G6	57+	290	41	42	40	41	43	128	0	
G9	59+	216	39	41	39	39	42	85	0	
G17	20-	234	39	37	29	29		26	0	
G19	28-	248	39		32	32		26	0	
G22	23-	102	38		28	28		26	0	
G31	10-	30	36	33	31	32		8	0	
SN↑	EL	AZ	C/A	L2CA	L1P	L2P	L3	TC	SS	FCN
R1	30	262	41	40	41	40		27	6	1
R7	46-	56	43	45	43	45		244	0	5
R8	71+	298	41	43	41	43		144	0	6
R9	25+	84	40	41	40	42		26	0	-2
R10	6+	130	37		37			3	0	-7
R16	21-	30	39	38	38	38		24	0	-1
R22	16-	186	39	30	38	31		287	0	-3
R23	58-	262	41	42	41	41		150	0	3
R24	38+	318	44	44	44	44		28	0	2

Without interference

Status NET-G5 ID:W1H2 VYFG

Position Misc SV List Sky Plot Scatter Position In Time Logging

PRN↑	EL	AZ	C/A	L2C	L1P	L2P	L5	TC	SS	
G1	4-	152	37	34	30	31	40	385	16	
G2	18+	316	43		28	28		36	0	
G3	44-	98	48	46	50	50	52	293	0	
G4	74-	92	48	53	45	44	57	189	0	
G6	57+	286	51	49	55	55	56	134	0	
G7	5+	176	37	33	29	30		3	0	
G9	59+	218	52	50	57	57	56	119	0	
G17	19-	234	41	38	29	29		238	0	
G19	26-	248	45		35	34		195	0	
G22	23-	104	43		30	31		346	0	
G25	1-	346	34	31	12	13	37	50	16	
G31	10-	30	38	35	35	35		182	0	
SN↑	EL	AZ	C/A	L2CA	L1P	L2P	L3	TC	SS	FCN
R1	30	264	47	43	46	43		63	6	1
R7	46-	58	54	52	52	52		245	0	5
R8	72+	300	53	56	52	55		152	0	6
R9	27+	84	50	49	49	48		61	0	-2
R10	7+	130	43		42			6	0	-7
R16	22-	28	43	42	42	41		114	0	-1
R22	14-	188	42	34	41	33		289	0	-3
R23	57-	260	57	48	56	48		153	0	3
R24	39+	316	54	50	53	49		79	0	2

# ANALYZING INTERFERENCE:

## Theoretical steps:

1. Spectrum analyses
2. Temporal analyses
3. Geographical analyses

## Practical implementation

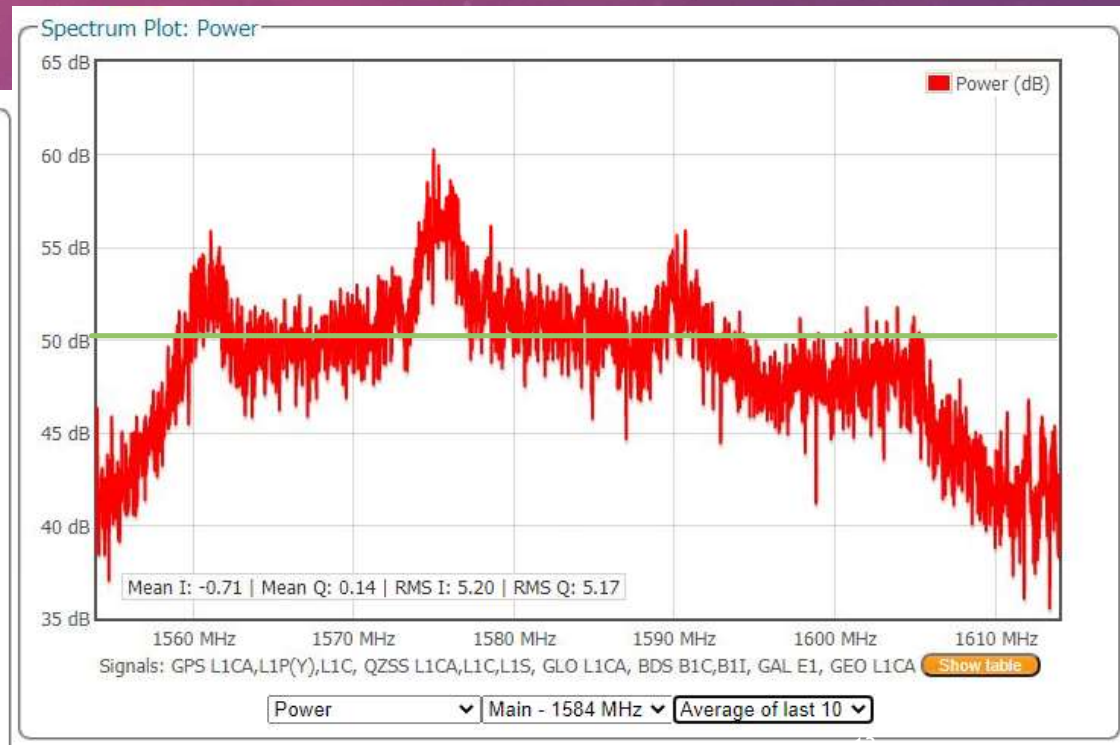
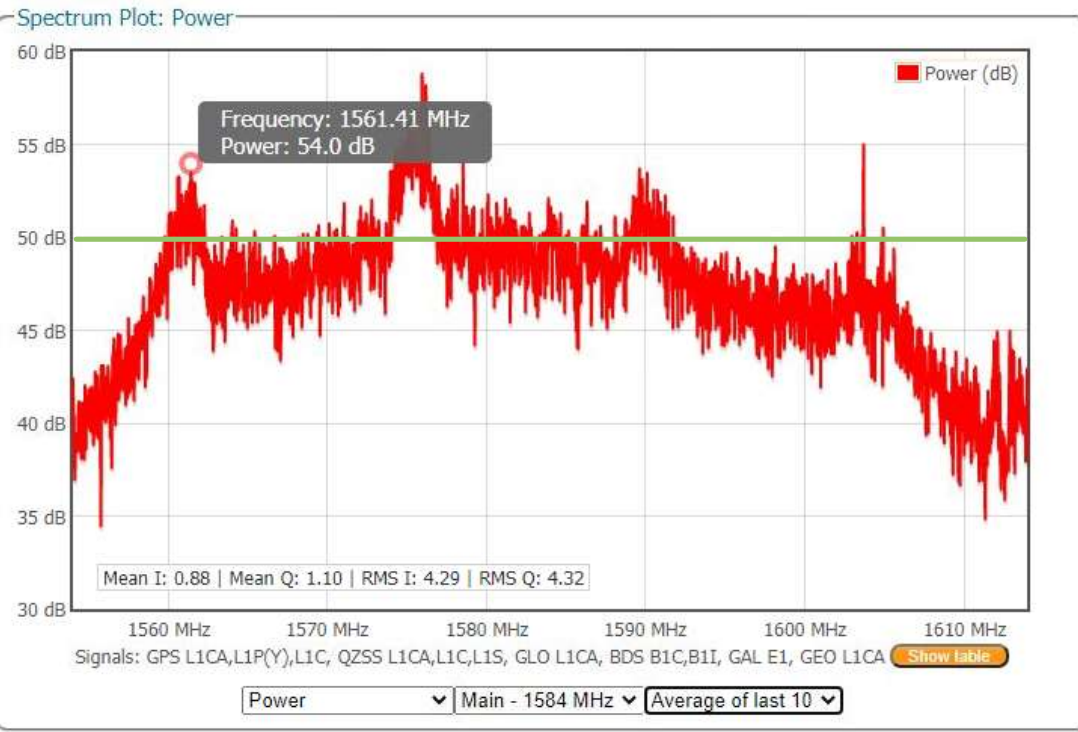
1. Spectrum plot of PolaRx5
2. Search in RINEX-log
3. plotting RINEX-log of all stations



# 1. SPECTRUM ANALYSIS

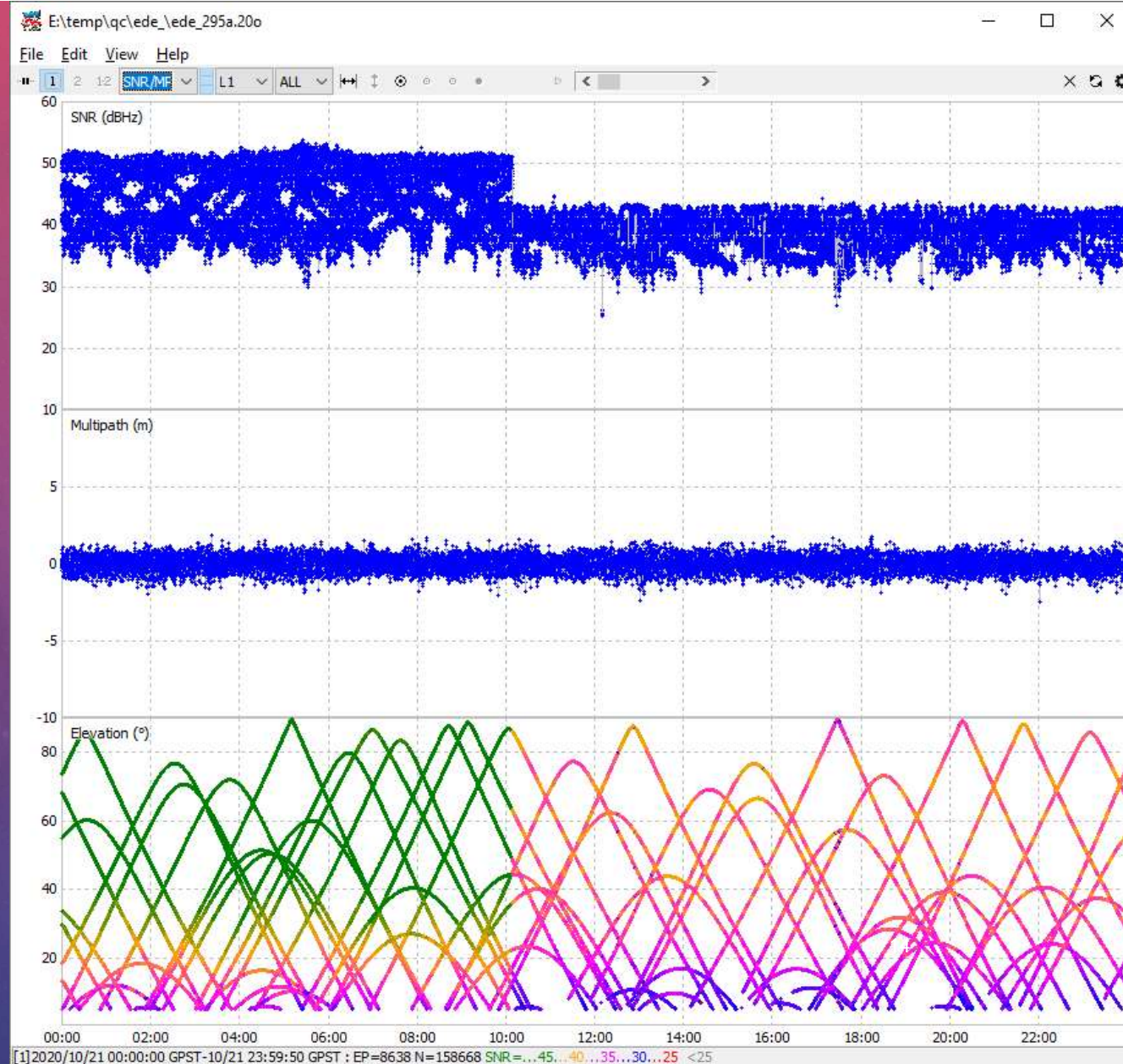
With interference

Without interference



## 2. TEMPORAL ANALYSES

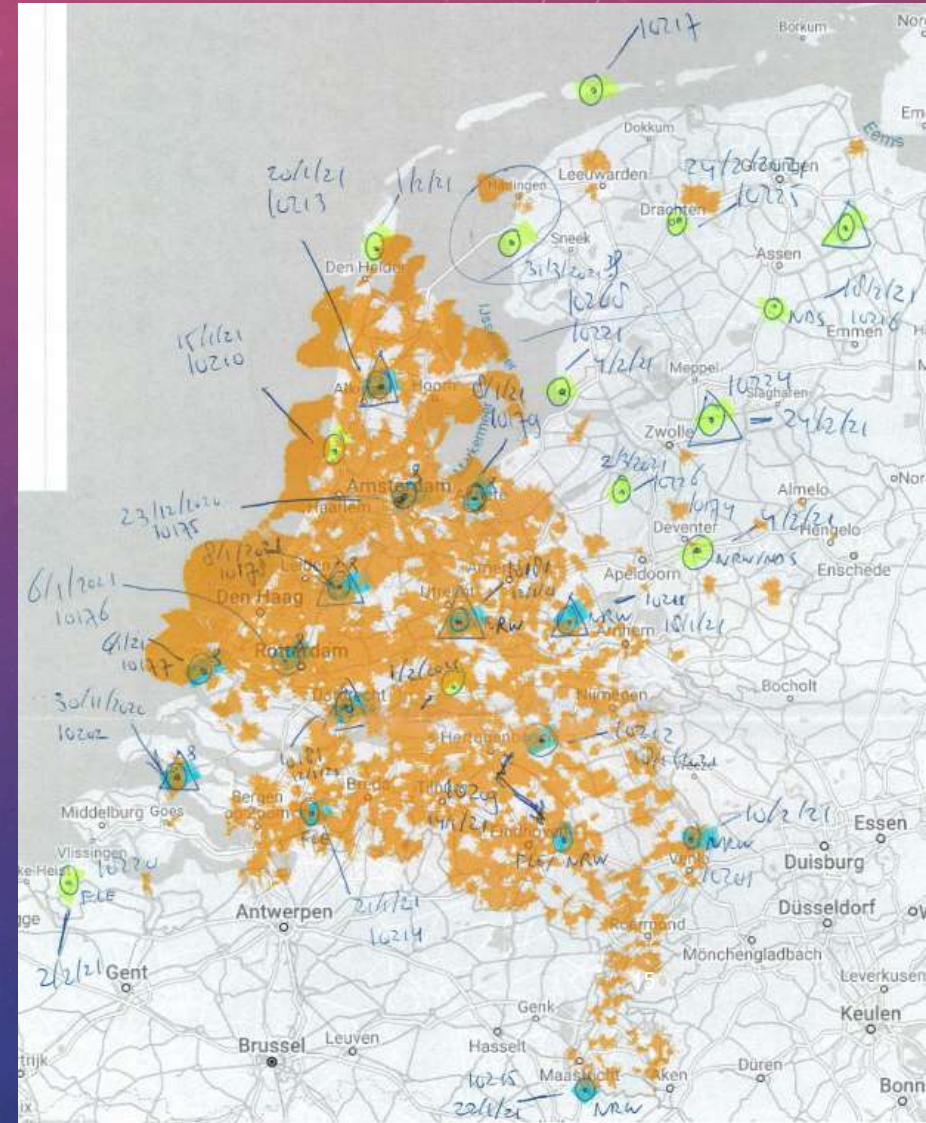
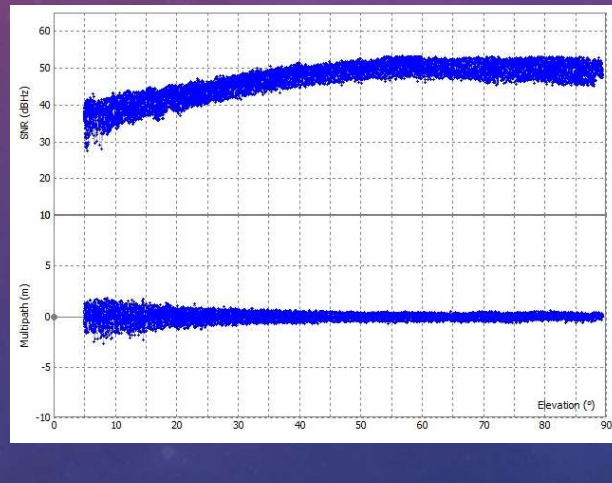
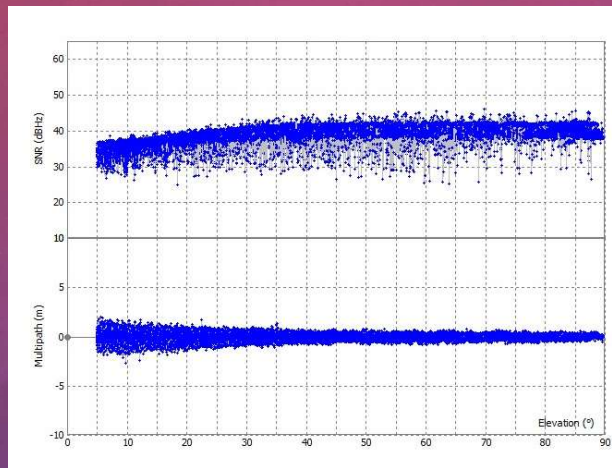
- Browsing the data to find the origin of the interference
- Use RTK-LIB to plot RINEX-log
- Interference started during the day as if a stationary signal was turned on
- 10 dB decrease (20%) !
- Station has 2 receivers on 1 antenna but only 1 receiver was affected.
- Only Topcon NET-G5 affected
- Septentrio PolaRX5 stayed unaffected





# GEOGRAPHICAL ANALYSES

A manual analysis show that KPN 5G-internet is directly correlated with the interference



# TEMPORAL FIT WITH THE CASE EDE

Using two different sources:

- List from KPN with maintenance date, time and location

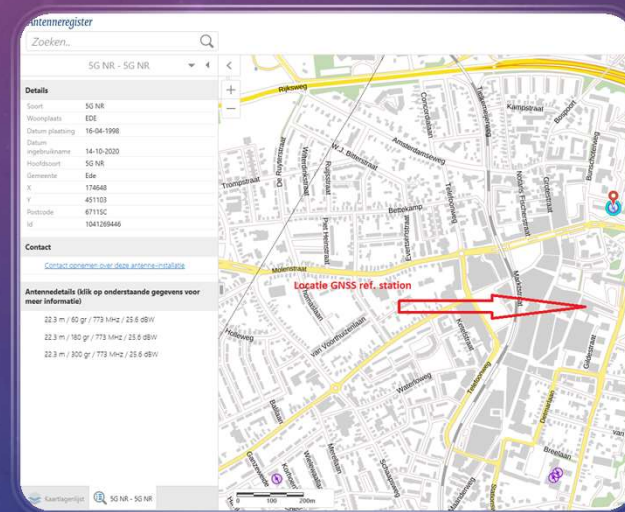
- Dutch antenna registry map

Mobile network maintenance and interference had an exact fit

Mobile network antenna pointed to our GNSS antenna.

During maintenance, 5G was also implemented

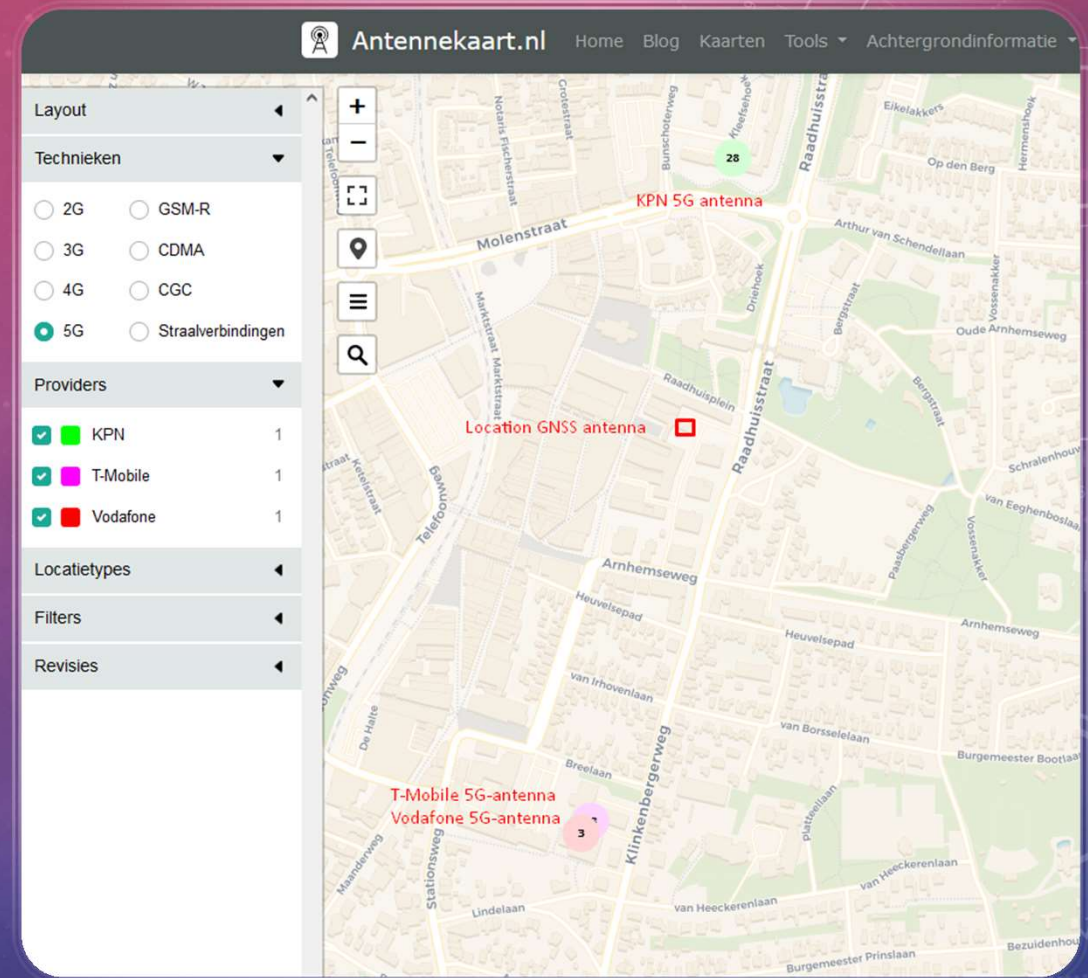
5G: 784 MHz -> 2<sup>nd</sup> harmonic: 1.568 MHz (close to GPS L1 1.575 MHz)

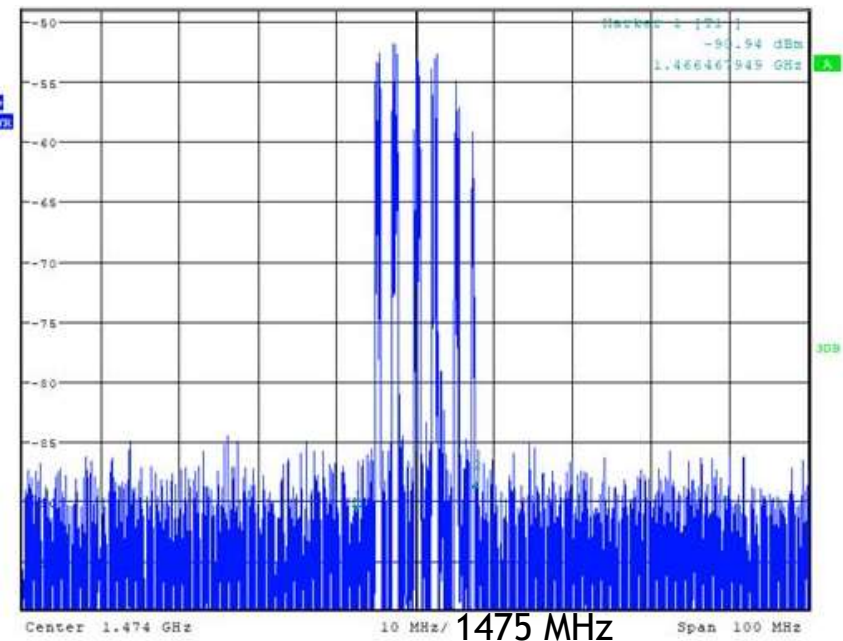




# INCONSISTANCIES WITHIN THE THEORY

- Other network providers turned on 5G-internet without causing interference.
- Only at KPN-antennas interference was found, providers Vodafone and T-Mobile have almost equal 5G-internet 700 MHz frequencies.





# COLLABORATING TO FIND PROBLEM

## Agentschap Telecom

Only KPN turned 4G LTE+ signal on  
4G LTE+ at 1.475 MHz

Only downlink (mast -> modem) due to possible interference  
of mobile-phone GPS

Field tests with 1.475 MHz radiator proved theory

## KPN

Took almost 3 months to get a technical response

5G didn't cause interference

4G LTE+ caused interference at frequency of 1.475 MHz

KPN temporary switching off LTE+ at station Ede was final prove

## Topcon

Conducted their own tests to find the issues with their equipment



# LOOKING INTO POSSIBLE SOLUTIONS

- Two types of attenuator
  - -20dB amplifier DC blocked
  - -40dB amplifier DC blocked
- Proposed new antenna
  - TPSCR.G5C choke ring with Cavity filter



Attenuator -40 dB with cooling



TPSCR.G5C



Attenuator -20 dB

# TEMPORARY STATION

Antennekaart.nl Home Blog Kaarten Tools Achtergrondinformatie Forum

Layout

Technieken

- 2G
- GSM-R
- 3G
- CDMA
- 4G
- CGC
- 5G
- Straalverbinding

Providers

Alles

- KPN
- T-Mobile
- Vodafone

Locatietypes

Filters

Revisies

**Crownpoint 1-3, Geldelozepad, Dordrecht, Zuid-Holland, Nederland, 3311WE, Nederland**

Provider KPN  
Plaats Dordrecht  
Gemeente Dordrecht  
Postcode 3311WD  
Site ID 7564

**Geschiedenis**

2020-07-29

Plaatsing 17 sep. 2004  
Gebruiksnaam 21 jul. 2020  
Veranderingen created

Hoogte	Hoek	Frequentie	Vermogen
28.8 m	30°	773 MHz	26.2 dBW
28.8 m	270°	773 MHz	26.2 dBW
29.7 m	150°	773 MHz	26.2 dBW





# TEST-SCENARIOS

1. Replication of 06-GPS station Dordrecht
2. Replication without antenna splitter
3. Replication with addition of band filter compact
4. Replication with addition of band filter cooled
5. Replication with non-amplified antenna splitter
6. Replication with new antenna “TPSCR.G5C      TPSH”

ANTENNA TPSCR.G5C

TPSH

Only the proposed antenna by Topcon could mitigate the interference!





# CAVITY FILTER MITIGATES NEAR BAND INTERFERENCE

## TPSCR.G5C

- Out of Band Rejection

- <1050 MHz : -80 dB
- 1051 - 1090 MHz : -60 dB ( 39 MHz)
- 1160 - 1300 MHz : - 0 dB (140 MHz) (L2/L3/L5)
- 1370 - 1510 MHz : -60 dB (140 MHz)
- 1540 - 1610 MHz : - 0 dB ( 70 MHz) (L1)
- 1670 - 1699 MHz : -60 dB ( 29 MHz)
- > 1700 MHz : -80 dB

Too broad: Out of band rejection

## TPSCR.G5

- Out of Band Rejection

- <1000 MHz : -60 dB
- 1001 - 1132 MHz : -60 dB (131 MHz)
- 1160 - 1300 MHz : - 0 dB (140 MHz) (L2/L3/L5)
- 1332 - 1418 MHz : -40 dB ( 86 MHz)
- 1515 - 1615 MHz : - 0 dB (100 MHz) (L1)
- 1718 - 1749 MHz : -40 dB ( 31 MHz)
- > 1750 MHz : -60 dB

Small rejection



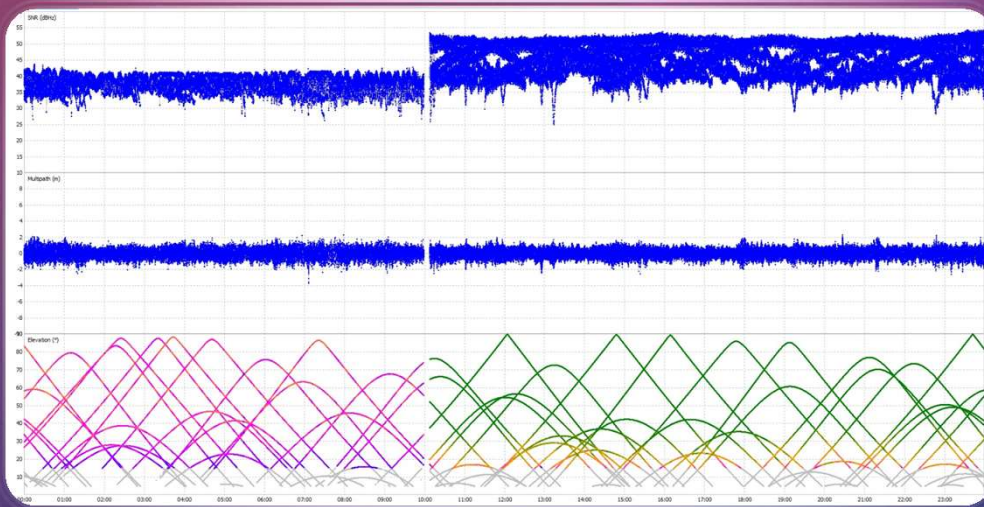
## IMPLEMENTING SOLUTION

Antenna change at 28 stations

Individual/group antenna calibration

Change logs to partners

End of 2021 Topcon will have an external device for antennas with no inbuild filter.





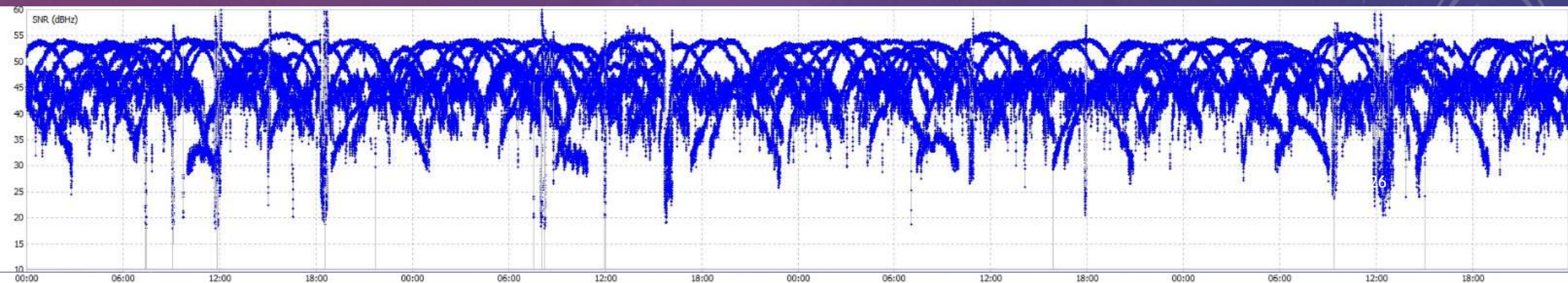
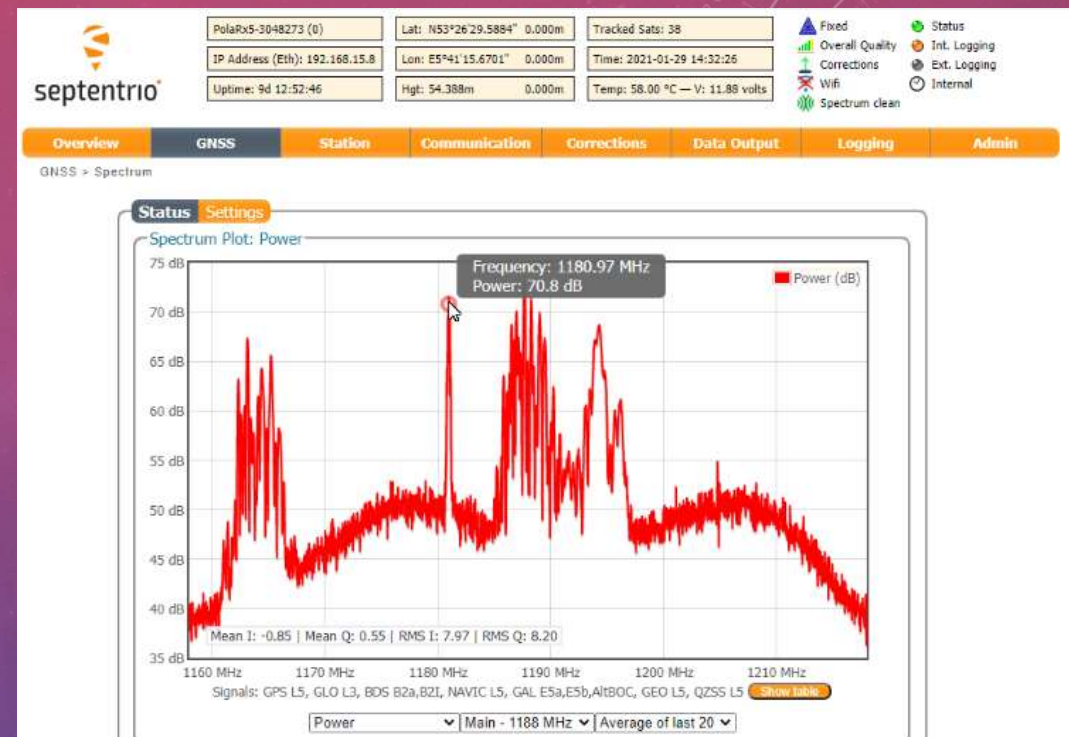


# CASE 2: RADIO AMATEUR INTERFERENCE

SINGLE STATION RADIO INTERFERENCE

# DISCOVERY OF INTERFERENCE

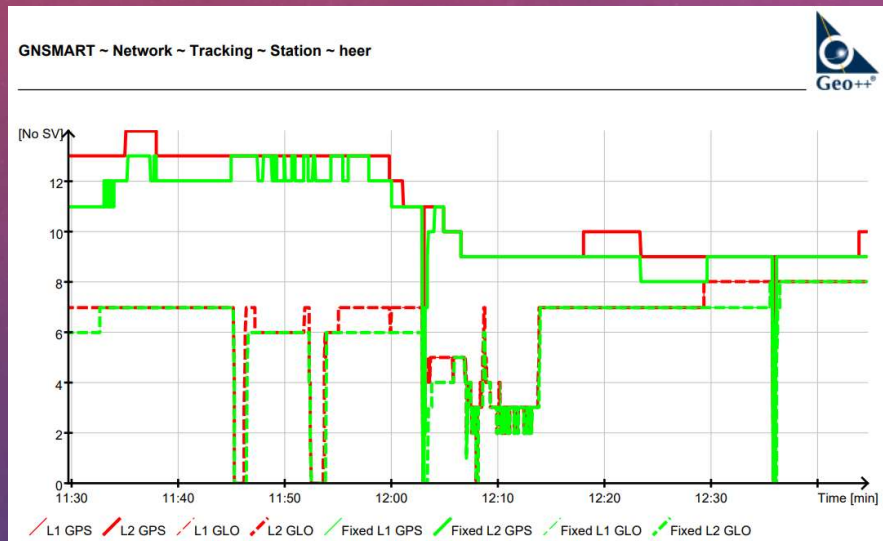
- Station Heerhugowaard
- Loss of fix in GNNET/GPPNET (GNSMART Geo++)
- Time depended, no exact schedule
- Only L2 of GPS & GLO affected



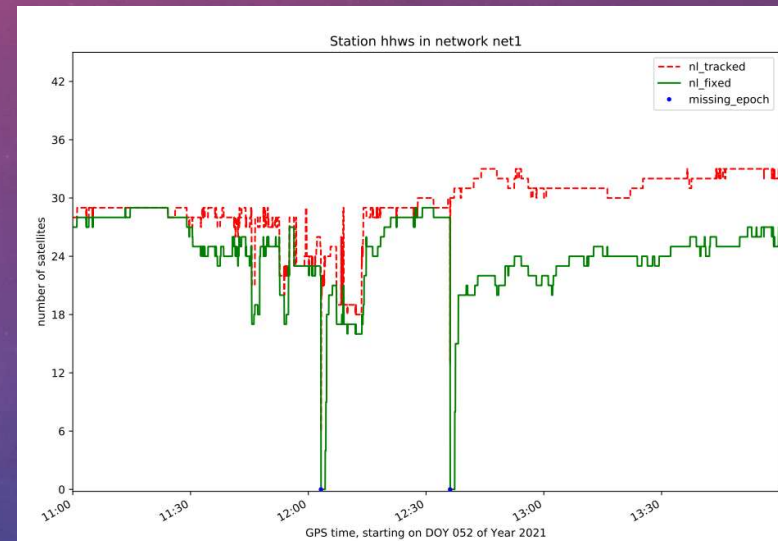


# EFFECT ON RTK-CORRECTIONS

## GNSMART v1 GNNET

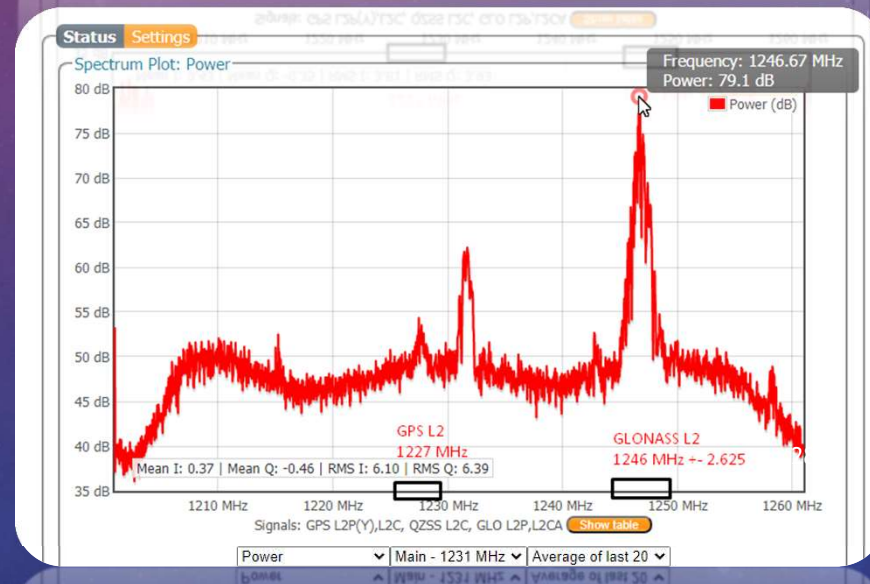
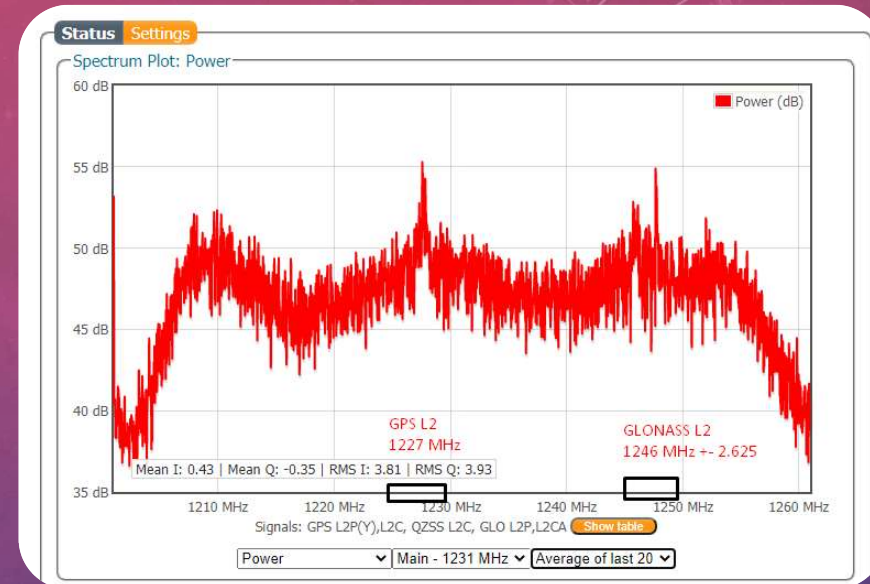


## GNSMART v2 GPPNET

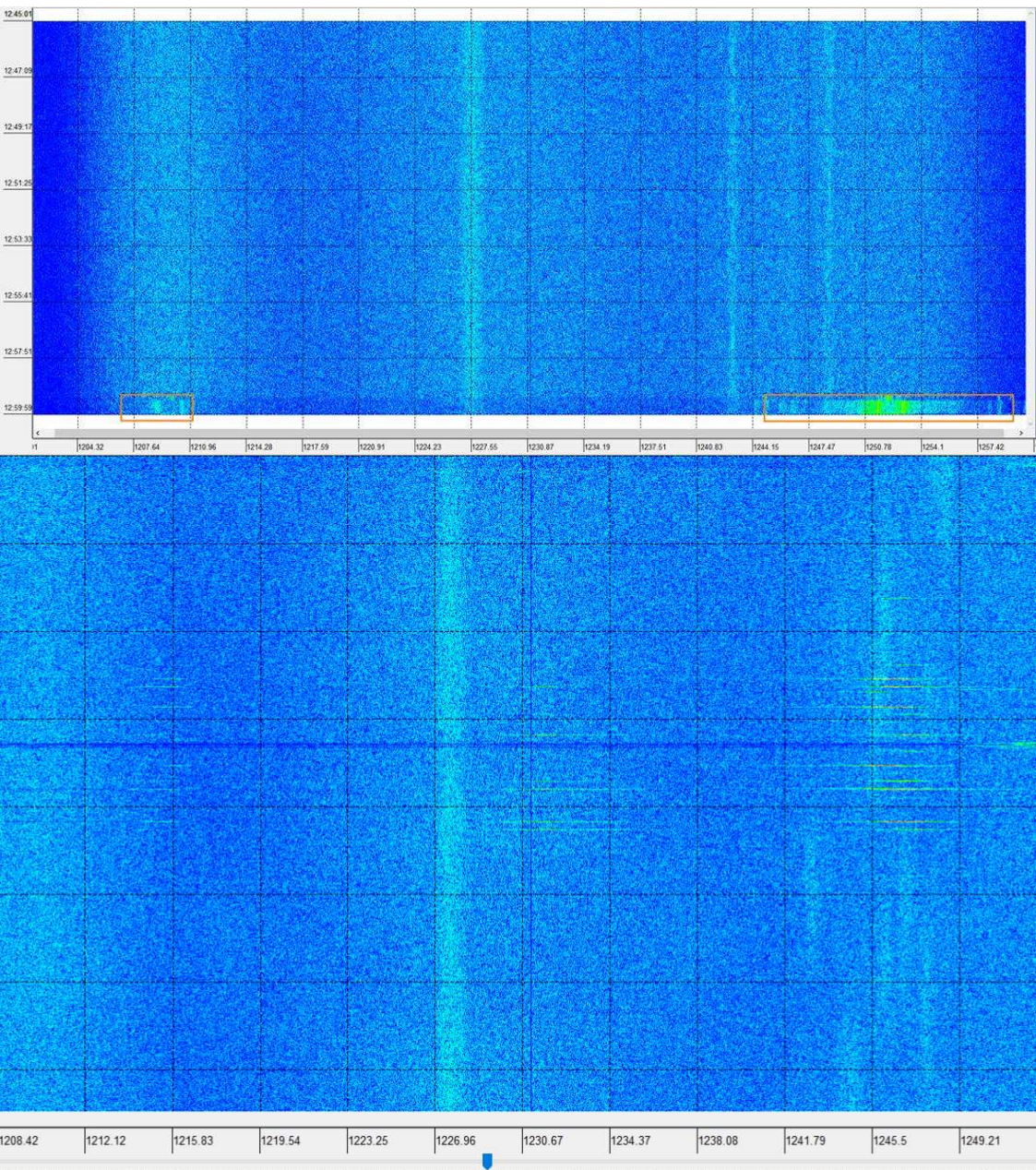


# SPECTRUM ANALYSES

Kanaal	GLO L1 MHz	GLO L2 MHz	PRN	Signaal	Freq. MHz
-7	1598.063	1242.938	10, 14	GPS L1	1575.42
-6	1598.625	1243.375		GPS L2	1227.60
-5	1599.188	1243.813		GPS L5	1176.45
-4	1599.750	1244.250	02, 06	GAL E1	1575.42
-3	1600.313	1244.688	18, 22	GAL E5a	1176.45
-2	1600.875	1245.125	09, 13	GAL E5b	1207.14
-1	1601.438	1245.563	12, 16	GAL E6	1278.75
0	1602.000	1246.000	11, 15	BDS B1	1561.10
1	1602.563	1246.438	01, 05	BDS B2	1207.14
2	1603.125	1246.875	20, 24	BDS B3	1268.52
3	1603.688	1247.313	01, 23		
4	1604.250	1247.750	17, 21		
5	1604.813	1248.188	03, 07		
6	1605.375	1248.625	04, 08		
7	1605.938	1249.063			







# SPECTRUM ANALYSES WITH SEPTENTRIO SUPPORT

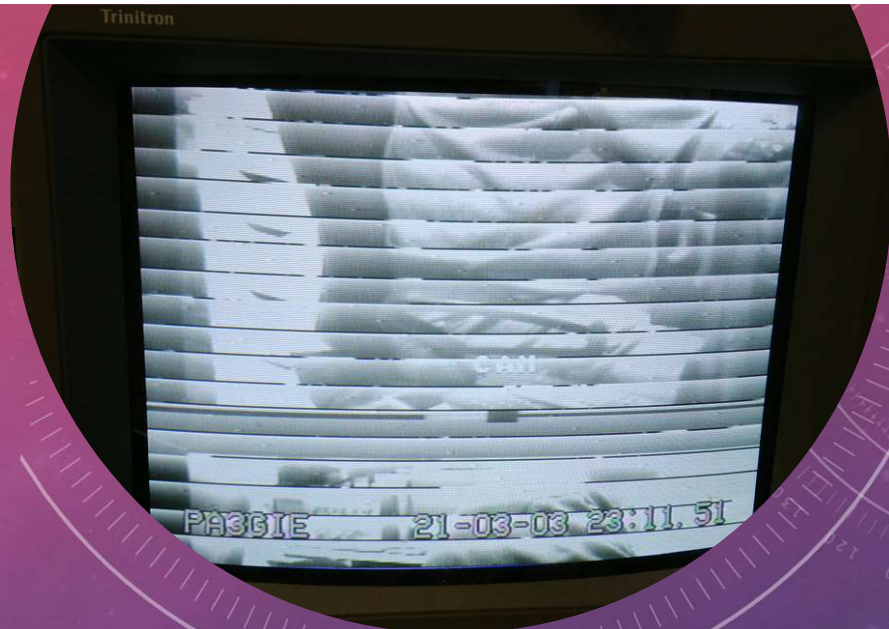
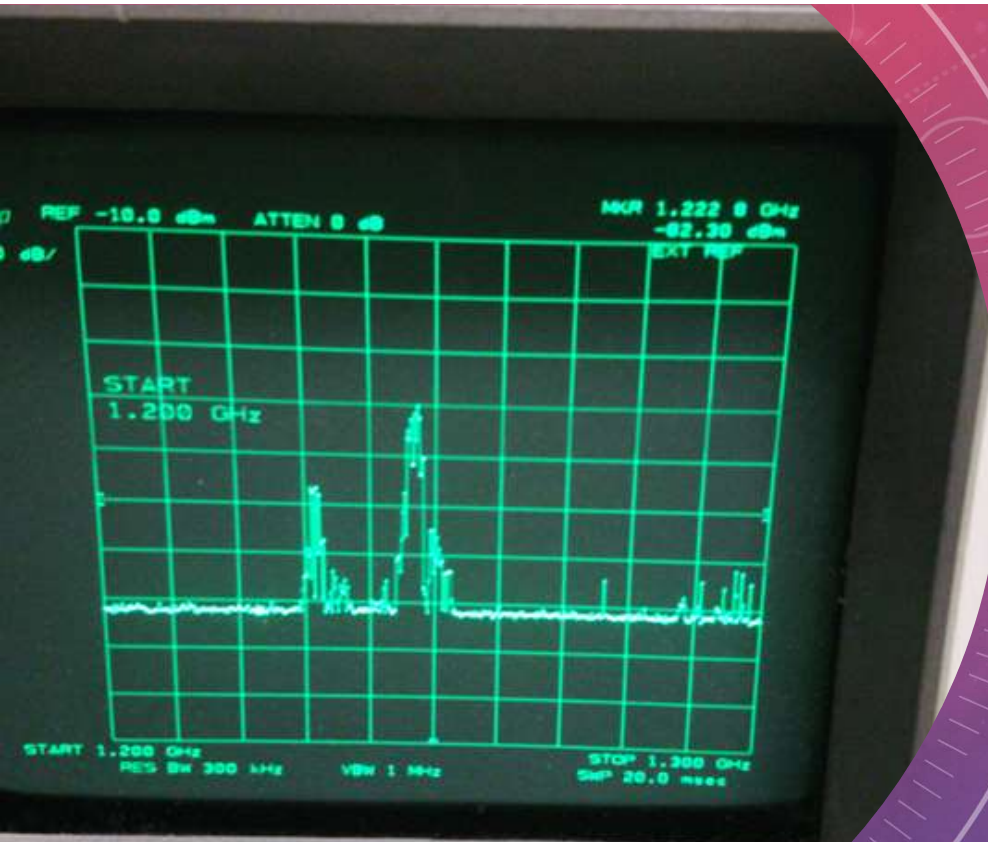


# SPATIAL ANALYSES

- Using antenna registry and street view to find radio amateurs
- Contact regional radio amateur association
- Email contact and plan a meeting







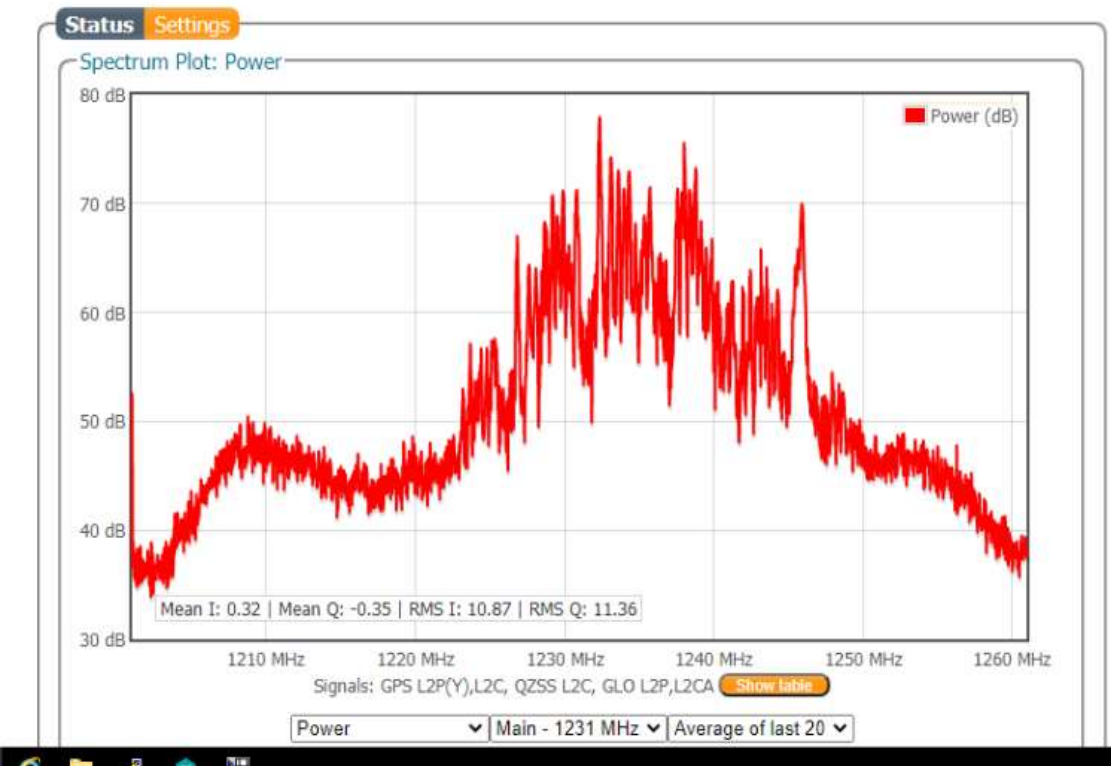
# RADIO AMATEUR ASSOCIATION SPECIALIZED IN VIDEO BROADCAST



JOINING THEIR MEETING  
FOR INTERACTIVE  
SPECTRUM TESTING  
Share screen with  
members Radio  
amateur association.

Every user tests their  
frequency and signal  
strength

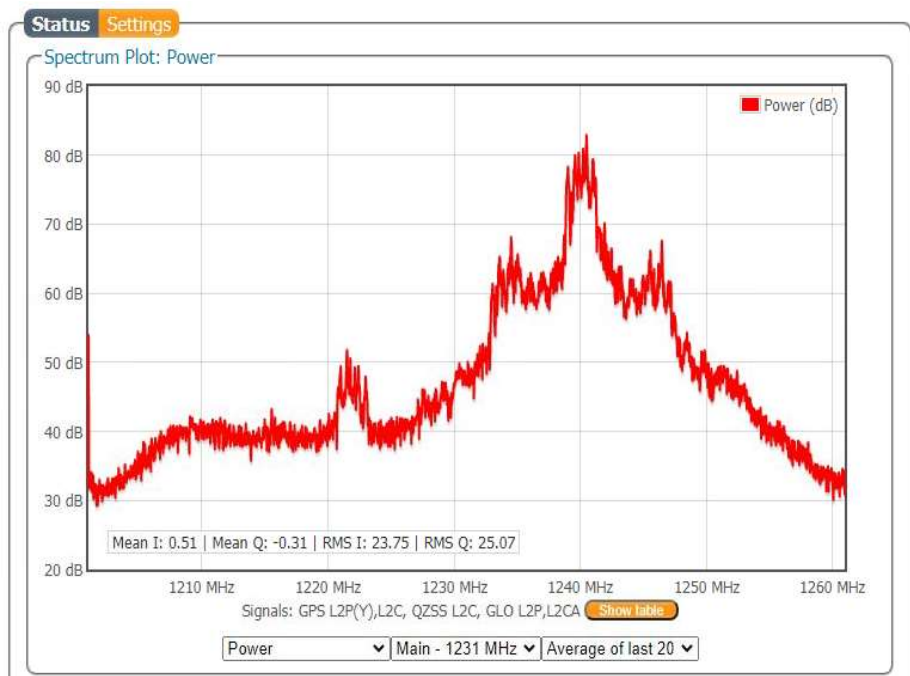
Life feedback, amount  
of interference shared





# ANALYSIS AND CONCLUSION

- During live feedback session the amateurs tested their broadcast limitation
  - 1 amateur used exactly GPS L2
  - 3 amateurs used GLONASS L2 to communicate
- Time-spectrum plot was shared afterwards
- Agreed to shift center frequency and lower power



# INTERFERENCE RETURNED

Informing various radio amateur associations

At one radio amateur television station there was a single user sending at 1240MHz exactly over the GNSS antenna.

No Telecom Agency involved

Monitoring performance GNSS-station with RINEX logs and network-performance

Radio Amateurs all moved to 1258 MHz





# CONCLUSIONS

Know normal GNSS SNR values and monitor receiver performance

There is always some interference, only focus on problematic interference

Use social-network while investigating problem.

The background features a gradient from red on the left to blue on the right, overlaid with faint technical diagrams. These include circular gauges with numerical scales (e.g., 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260) and various circular arrows indicating clockwise or counter-clockwise rotation.

**THANK YOU FOR YOUR  
ATTENTION !**