

Recibiendo telemetría satelital por diversión

- RF Village @ BugCon 2024
- Manuel Rábade manuel@rabade.net

Satélites GEO, MEO y LEO

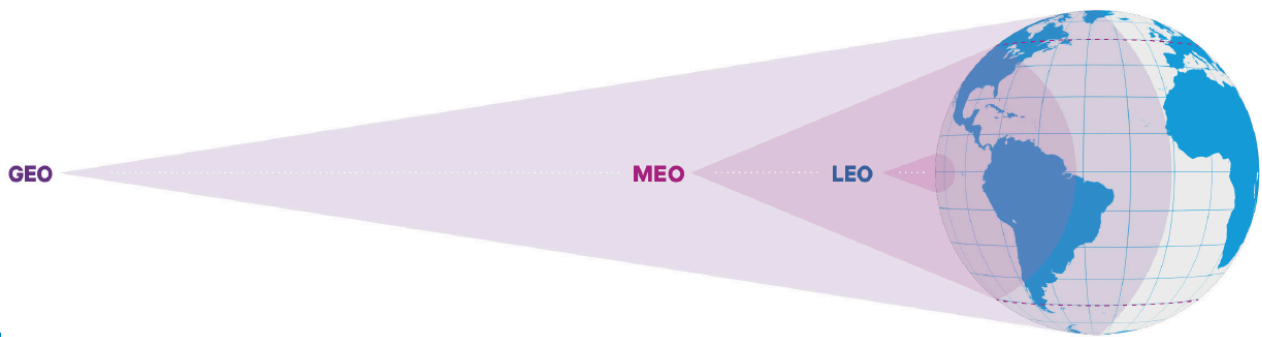


Figure 1: Schematic of orbital altitudes and coverage areas

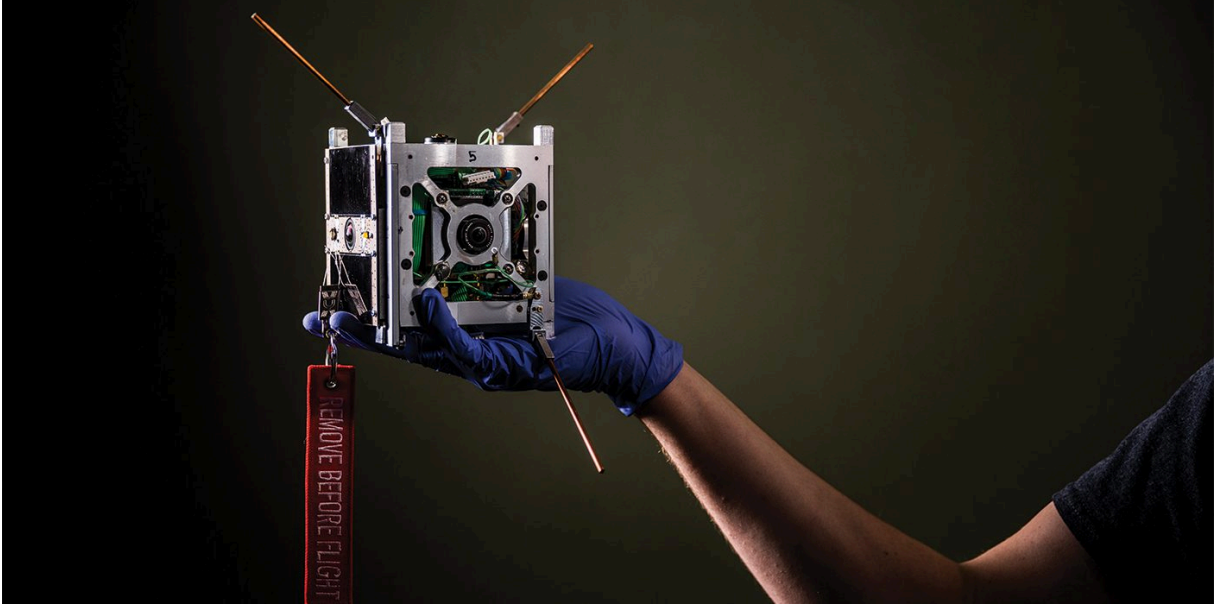
<https://www.satellitetoday.com/content-collection/ses-hub-geo-meo-and-leo/>

Vehículo/Objeto	Altura	Peso	Velocidad
Aviones comerciales	10 - 13 km	70 - 400 t	~900 km/h
Aviones militares	15 - 20 km	10 - 40 t	~2,000 km/h
Concorde	15 - 18 km	78 t	~2,180 km/h
CanSats	15 km	0.05 - 0.1 kg	N/A
CubeSats	200 - 2,000 km	1 - 20 kg	~28,000 km/h (7.8 km/s)
Órbita baja (LEO)	200 - 2,000 km	100 - 2,000 kg	~28,000 km/h (7.8 km/s)
Estación Espacial (ISS)	400 - 420 km	420 t	~28,000 km/h (7.8 km/s)
GPS (MEO)	20,200 km	1 - 2 t	~14,000 km/h (3.9 km/s)
Geostacionaria (GEO)	35,786 km	2 - 6.5 t	~11,000 km/h (3.1 km/s)

CubeSats

- Órbita baja (LEO)
 - 1 orbita cada ~90 minutos (128 minutos o menos)

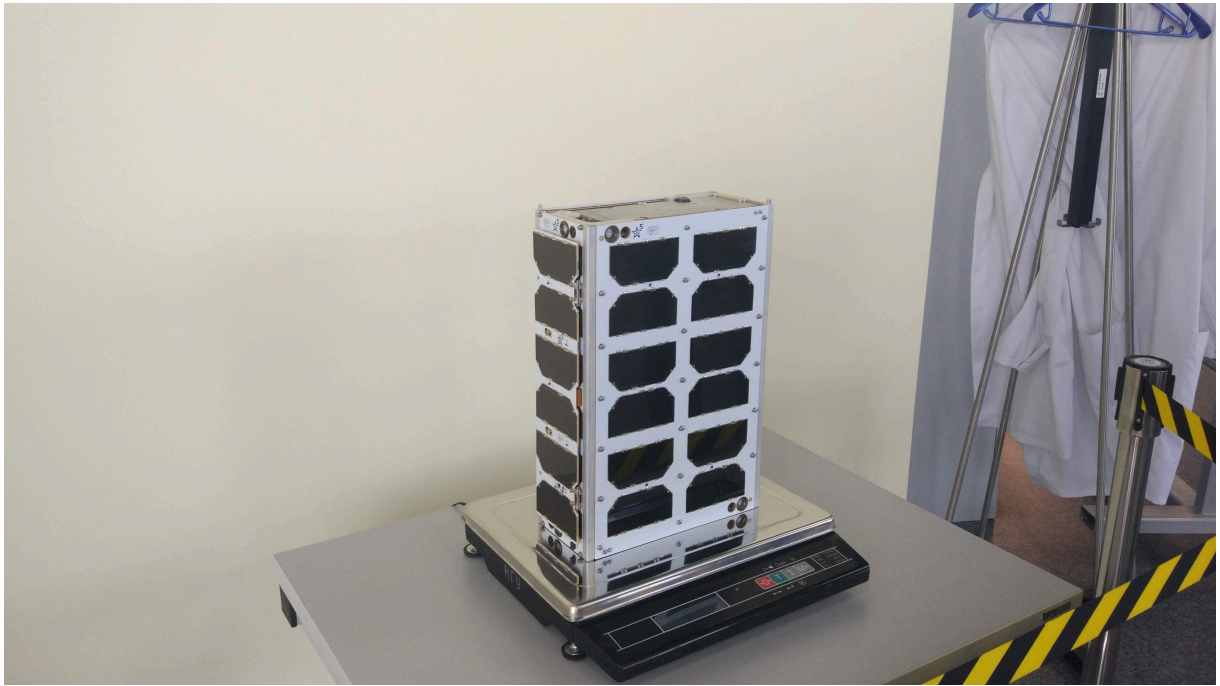
- 200 - 2,000 km, $e < 0.25$
 - ISS: 330-410 km, $e = 0$
- Dentro de los cinturones de Van Allen: La electrónica requiere menos blindaje contra la radiación
- CubeSats
 - 10 cm³ y menos de 1.33 kg



<https://magazine.byu.edu/article/cubesat/>

- 1U, 2U, 3U, ...
 - Para 1U:
 - Fabricación: 50-100k USD
 - Lanzamiento: 20-50k USD por Kg
- 2-5 años de vida útil

- Norby (6U, Sep 2020, 550-580 Km, 82°)



<https://tinygs.com/satellite/Norby>

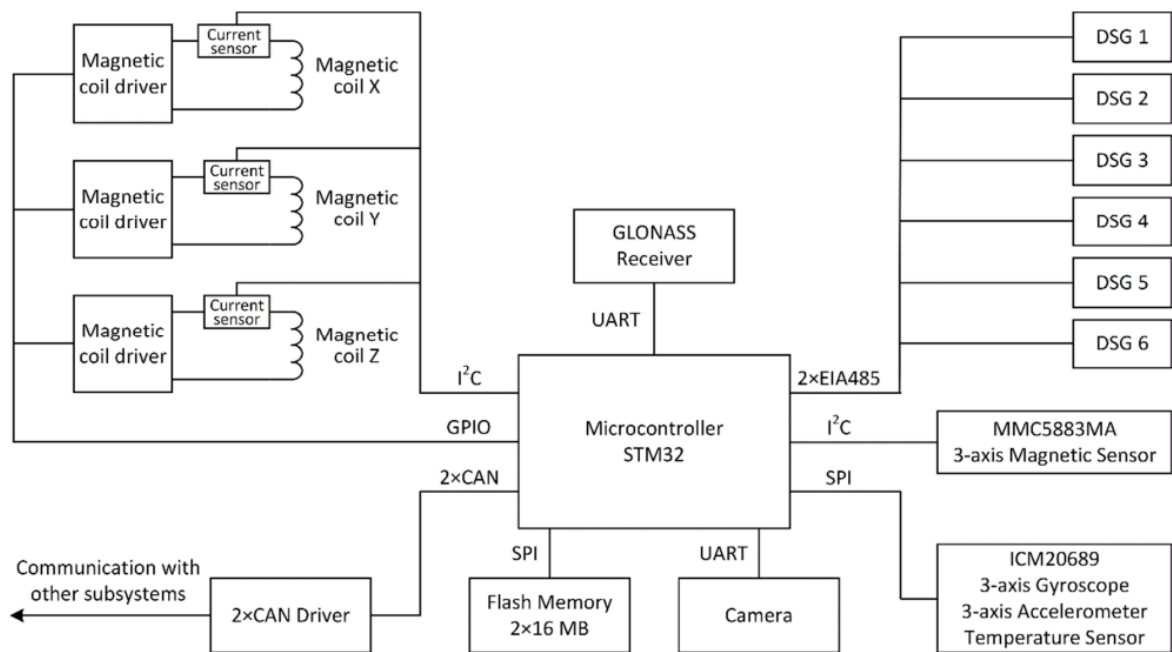


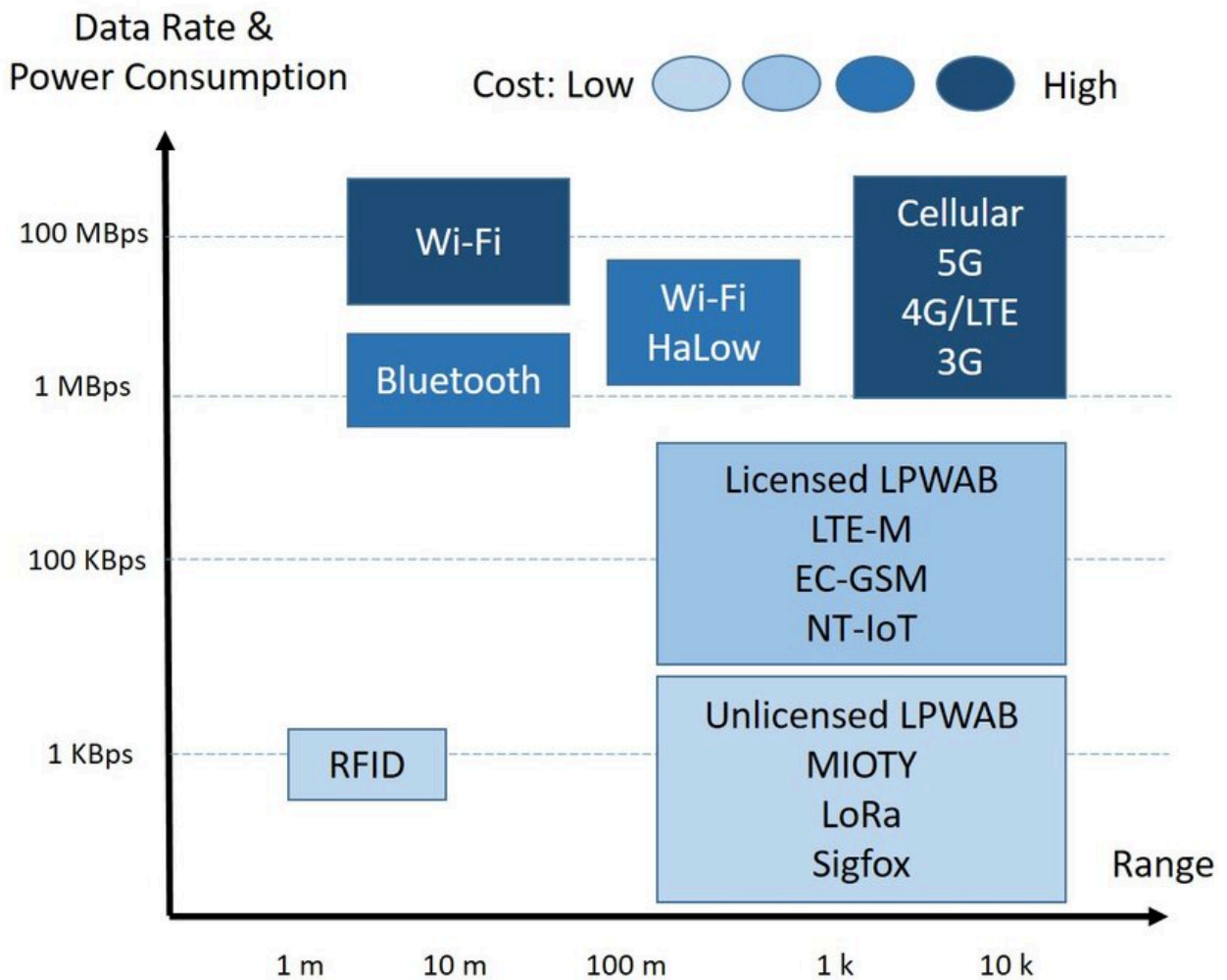
Figure 5. Structural block diagram of the NORBY attitude determination and control system.

<https://iopscience.iop.org/article/10.1088/1742-6596/1867/1/012038/pdf>

LoRa

- LOnG RAnge transmissions with low power consumption
- Capa física, 0.3-27 kbit/s
- Frecuencias libres: 169 MHz, 433 MHz, 868 MHz, 915 MHz

- Alternativas: Sigfox o ZigBee



<https://www.beei.org/index.php/EEI/article/view/5214/3490>

TinyGS

- Web: <https://tinygs.com/>
 - Repo: <https://github.com/G4lile0/tinyGS>
 - Wiki: <https://github.com/G4lile0/tinyGS/wiki>
- TLE
 - <https://github.com/4m1g0/tinygs-wiki/blob/master/TLE.md>
 - https://api.tinygs.com/v1/tinygs_supported.txt
- Alternativas
 - <https://satnogs.org>
 - <https://vayuvani.com>

- Norby:

Norby

Received on: November 19, 2024 4:42 AM
 LoRa 436.703 Mhz SF: 10 CR: 5 BW: 250 kHz
 Sat in Umbra ■ Eclipse Depth: 11.21°
 Theoretical coverage 4853 km

🏠 7000mW 🌡️ 21°C
 🔌 8238mV 🔋 1896mW 🌡️ 21°C
 ☀️ 0mW 🔋 13011mAh 🌡️ -2482mW
 🌡️ Board PMM: 12°C PAM: 12°C PDM: 9°C
 🌡️ Solar Array X-: -5°C X+: -6°C
 📶 3013.42344

Hexadecimal view Download

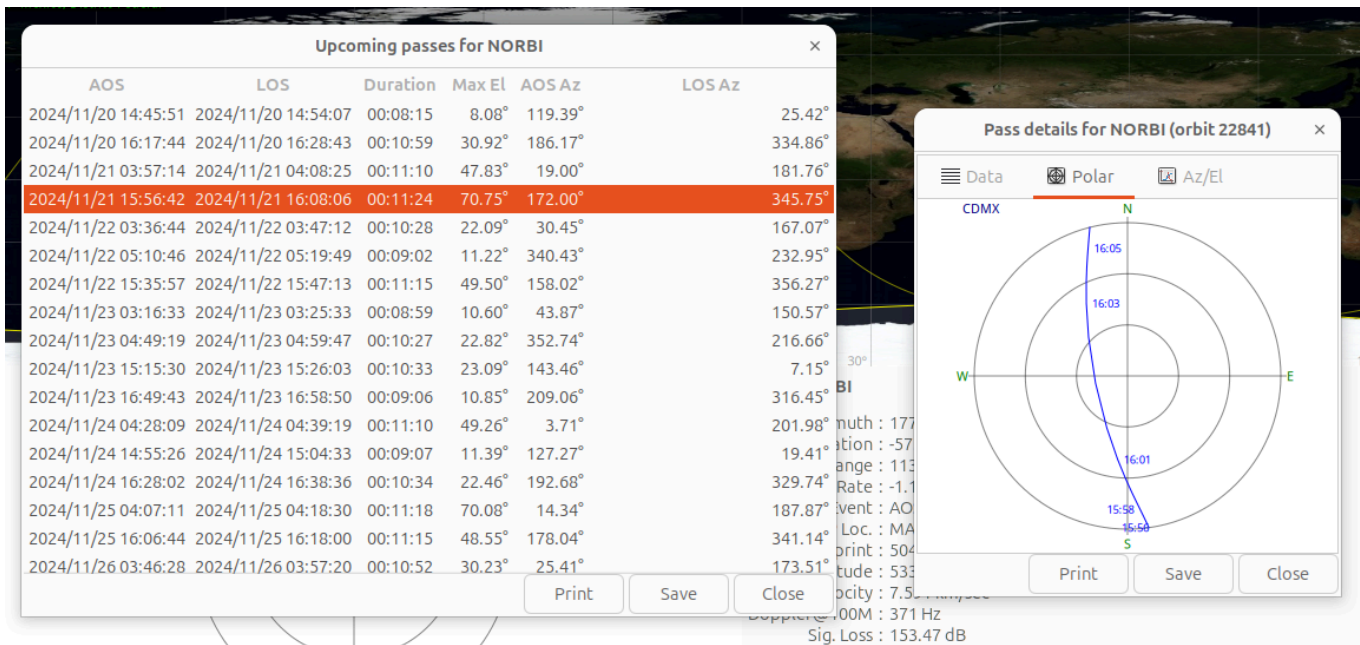
	0	1	2	3	4	5	6	7	8	012345678
0000	8E	FF	FF	FF	FF	0A	06	01	C9
0009	34	84	00	00	00	00	F1	0F	00	4.....
0012	00	68	A5	5C	8A	CF	2E	42	52	.h.\...BR
001B	4B	20	4D	57	20	56	45	52	3A	K MW VER:
0024	30	35	61	5F	30	31	00	00	00	05a_01...

<https://tinygs.com/packet/e1830dc5-a171-4a1d-b1ad-03d756beab6d>

Demo BugCon

- <https://tinygs.com/station/BugCON@28776673>
- <http://192.168.247.15>

Pases satélites



<https://oz9aec.dk/gpredict/>

Satélite	21/nov	22/Nov
Norby	15:56 @ 70°	15:35 @ 49°
Pico-1B-2	11:09 @ 60°	11:09 @ 60°
Pico-1B-5	11:26 @ 74°	11:26 @ 72°
Tianqi-27	17:10 @ 67°	17:11 @ 47°
Tianqi-28	16:44 @ 76°	16:44 @ 75°
Tianqi-29	18:18 @ 66°	18:06 @ 79°
Tianqi-30	18:42 @ 83°	18:30 @ 70°

Recepciones previas Tianqi-27

- 21/nov 02:22: 2378 km @ 12°
- 21/nov 02:28: 898 km @ 86°
- 21/nov 02:29 1007 km @ 60°

Tianqi-27 Nov 21, 2024 02:29:15 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 1007Km	Elevation 60.94°	RSSI -123.25 dBm	SNR -11.25 dB	Predicted Doppler -3990.73Hz	Frequency Error 1434.45Hz	CRC Error	Received by 7 Stations
Tianqi-27 Nov 21, 2024 02:28:00 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 898Km	Elevation 86.33°	RSSI -123 dBm	SNR -10 dB	Predicted Doppler 366.36Hz	Frequency Error -3347.05Hz	CRC Error	Received by 5 Stations
Tianqi-27 Nov 21, 2024 02:26:45 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 1043Km	Elevation 56.95°	RSSI -124.5 dBm	SNR -11.5 dB	Predicted Doppler 4481.90Hz	Frequency Error -7994.34Hz	CRC Error	Received by 9 Stations
Tianqi-27 Nov 21, 2024 02:25:15 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 1438Km	Elevation 33.68°	RSSI -124 dBm	SNR -11 dB	Predicted Doppler 6853.23Hz	Frequency Error -10443.82Hz	CRC Error	Received by 11 Stations
Tianqi-27 Nov 21, 2024 02:25:00 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 1516Km	Elevation 30.93°	RSSI -121.25 dBm	SNR -9.25 dB	Predicted Doppler 7065.01Hz	Frequency Error -10846.47Hz	CRC Error	Received by 12 Stations
Tianqi-27 Nov 21, 2024 02:24:45 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 1596Km	Elevation 28.41°	RSSI -120.75 dBm	SNR -8.75 dB	Predicted Doppler 7244.62Hz	Frequency Error -10796.14Hz	CRC Error	Received by 10 Stations
Tianqi-27 Nov 21, 2024 02:24:30 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 1679Km	Elevation 26.10°	RSSI -119 dBm	SNR -7 dB	Predicted Doppler 7397.32Hz	Frequency Error -10997.46Hz	CRC Error	Received by 8 Stations
Tianqi-27 Nov 21, 2024 02:24:15 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 1762Km	Elevation 23.96°	RSSI -121.75 dBm	SNR -8.75 dB	Predicted Doppler 7527.47Hz	Frequency Error -11299.46Hz	CRC Error	Received by 7 Stations
Tianqi-27 Nov 21, 2024 02:24:00 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 1848Km	Elevation 21.98°	RSSI -121.75 dBm	SNR -9.75 dB	Predicted Doppler 7638.67Hz	Frequency Error -11450.45Hz	CRC Error	Received by 9 Stations
Tianqi-27 Nov 21, 2024 02:23:45 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 1934Km	Elevation 20.14°	RSSI -121.5 dBm	SNR -8.5 dB	Predicted Doppler 7733.87Hz	Frequency Error -11349.79Hz	CRC Error	Received by 1 Stations
Tianqi-27 Nov 21, 2024 02:23:30 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 2021Km	Elevation 18.43°	RSSI -119.75 dBm	SNR -7.75 dB	Predicted Doppler 7815.52Hz	Frequency Error -11450.45Hz	CRC Error	Received by 1 Stations
Tianqi-27 Nov 21, 2024 02:23:15 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 2109Km	Elevation 16.82°	RSSI -120.75 dBm	SNR -8.75 dB	Predicted Doppler 7885.63Hz	Frequency Error -11685.33Hz	CRC Error	Received by 1 Stations
Tianqi-27 Nov 21, 2024 02:23:00 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 2198Km	Elevation 15.31°	RSSI -122 dBm	SNR -9 dB	Predicted Doppler 7945.84Hz	Frequency Error -11718.89Hz	CRC Error	Received by 1 Stations
Tianqi-27 Nov 21, 2024 02:22:45 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 2288Km	Elevation 13.88°	RSSI -122.5 dBm	SNR -10.5 dB	Predicted Doppler 7997.55Hz	Frequency Error -11635.00Hz	CRC Error	Received by 1 Stations
Tianqi-27 Nov 21, 2024 02:22:30 (10 hours ago)	Mode LoRa@400.45	Power 9000mW	Distance 2378Km	Elevation 12.53°	RSSI -124 dBm	SNR -11 dB	Predicted Doppler 8041.90Hz	Frequency Error -11718.89Hz	CRC Error	Received by 1 Stations