GNSS INTRODUCTION

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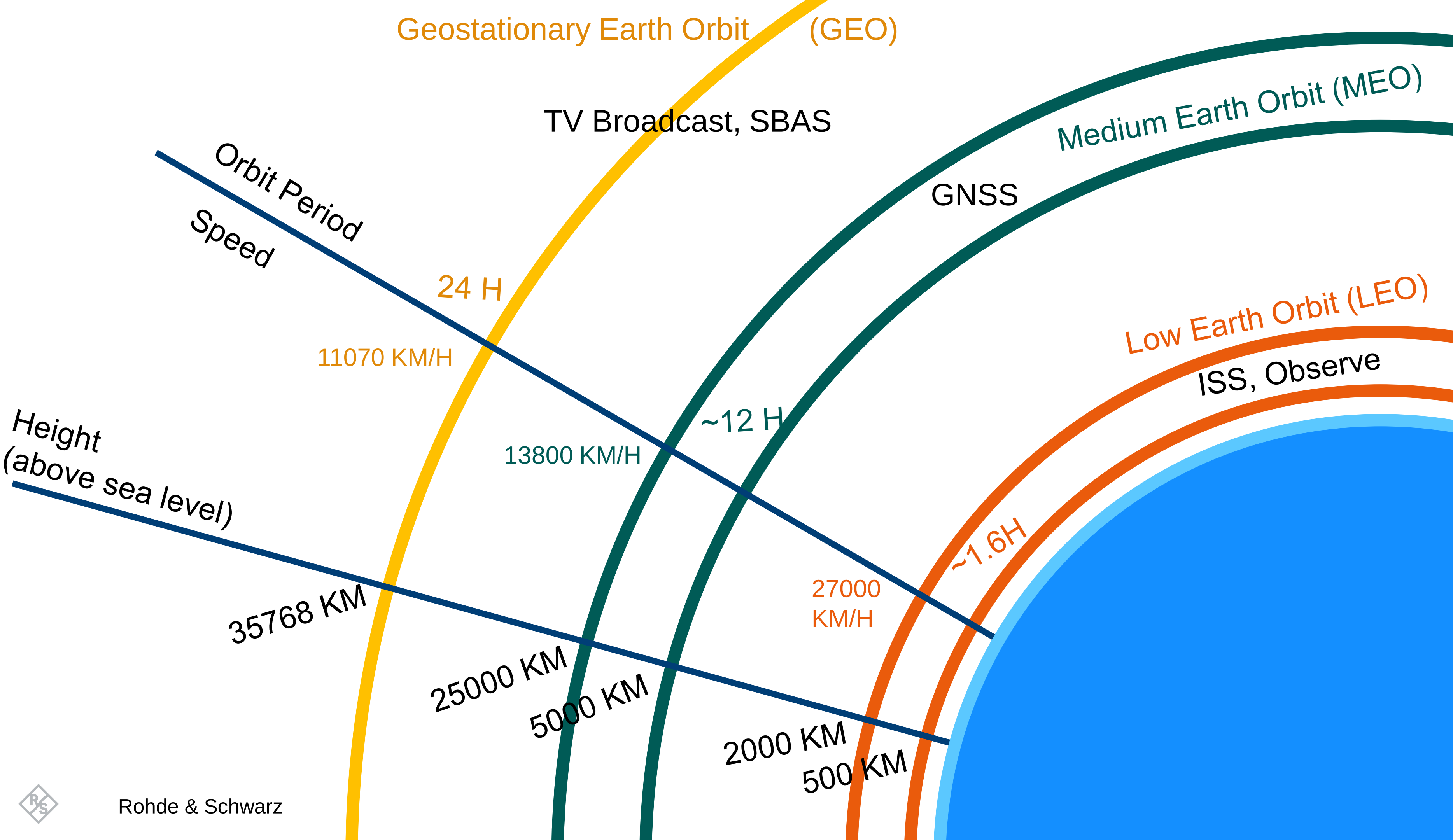
ROHDE&SCHWARZ

Make ideas real

WHAT IS GNSS?

GLOBAL NAVIGATION SATELLITE SYSTEM



Geostationary Earth Orbit (GEO)
TV Broadcast, SBAS
Medium Earth Orbit (MEO)
GNSS
Low Earth Orbit (LEO)
ISS, Observe
Orbit Period
Speed
24 H
11070 KM/H
~12 H
13800 KM/H
~1.6H
27000 KM/H
Height (above sea level)
35768 KM
25000 KM
5000 KM
2000 KM
500 KM

Kepler's law

First law

$$r = \frac{p}{1 + \varepsilon \cos\theta}$$

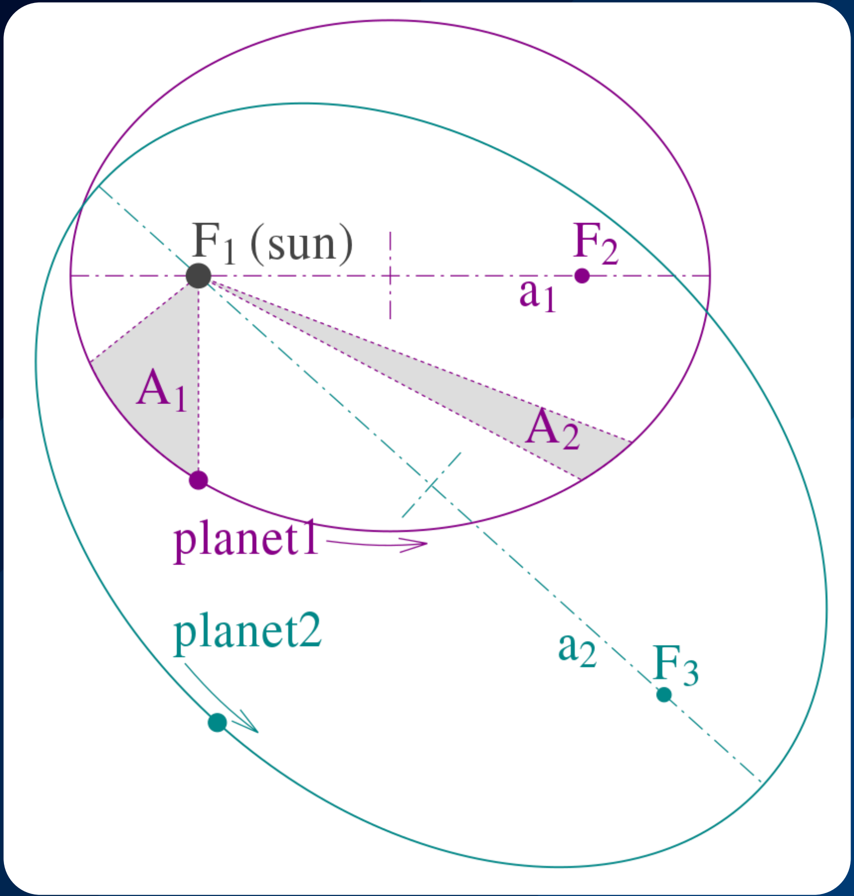
Second law

$$A_1 = A_2$$

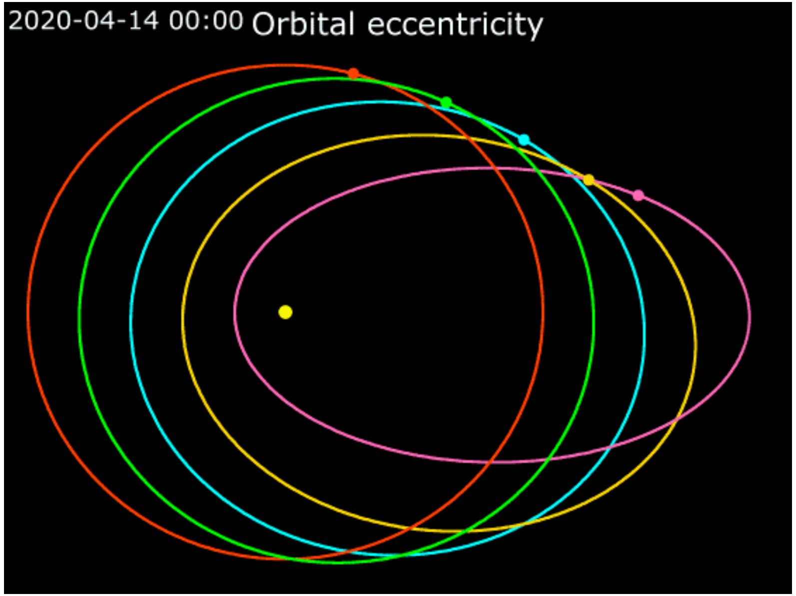
Third law

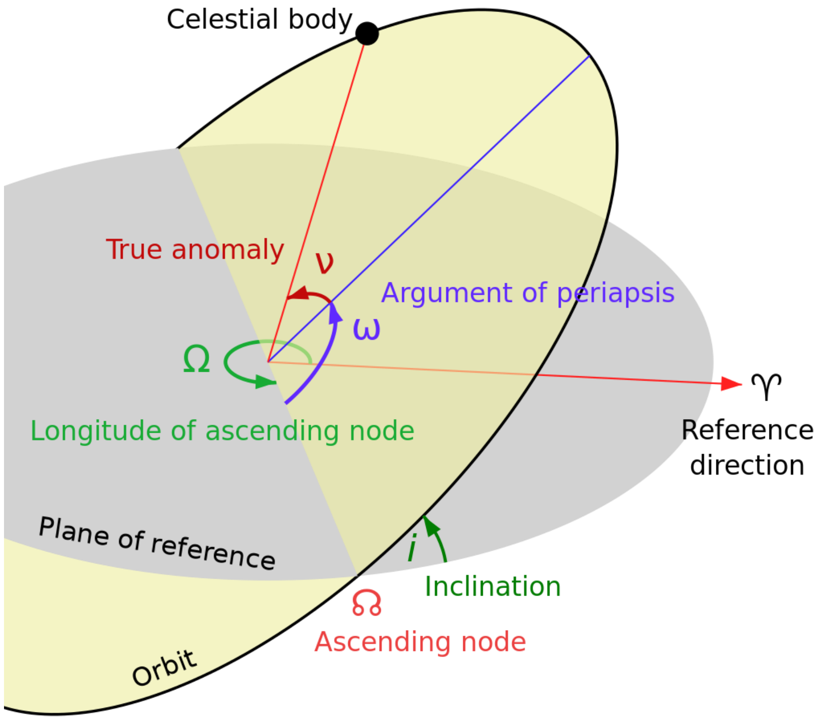
$$\frac{a^3}{T^2} = Constant$$

$$V^2 * r = Constant = \frac{4\pi^2 r^3}{T^2}$$

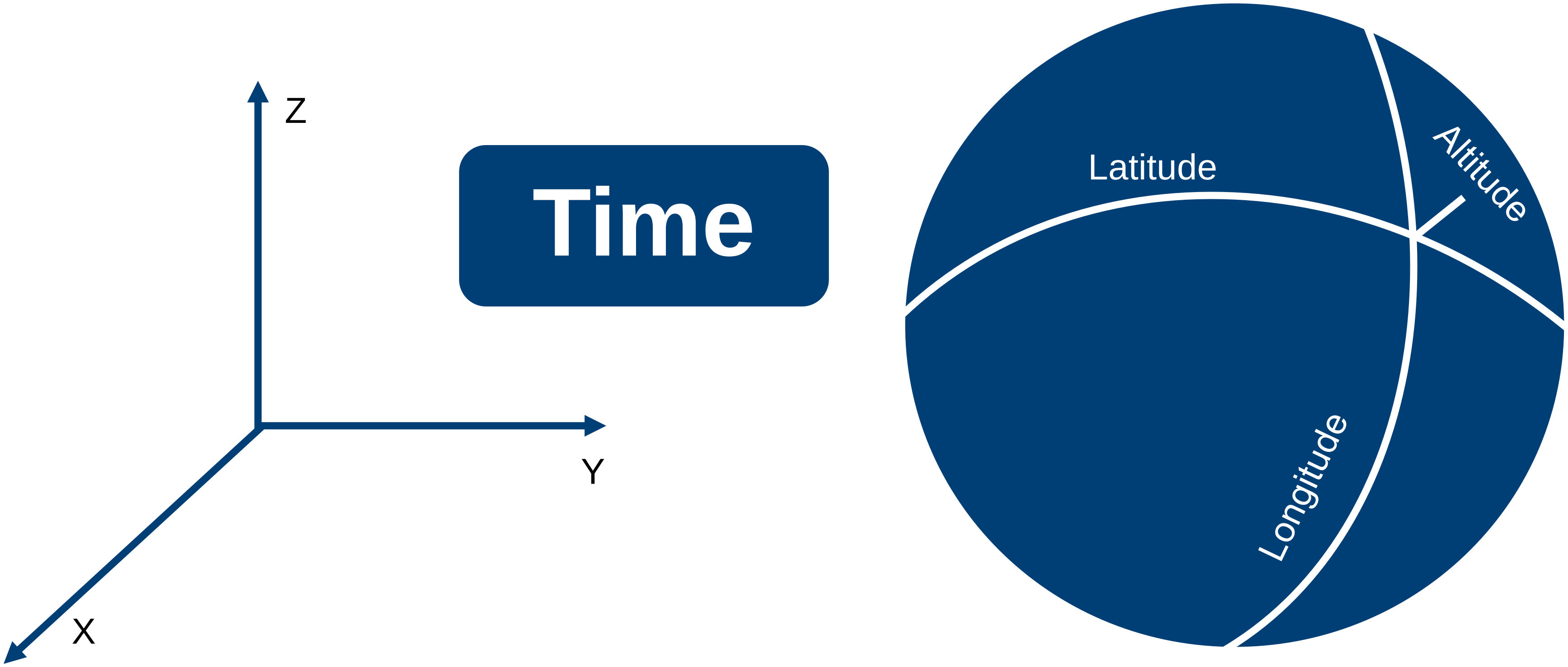


INCLINATION & ECCENTRICITY





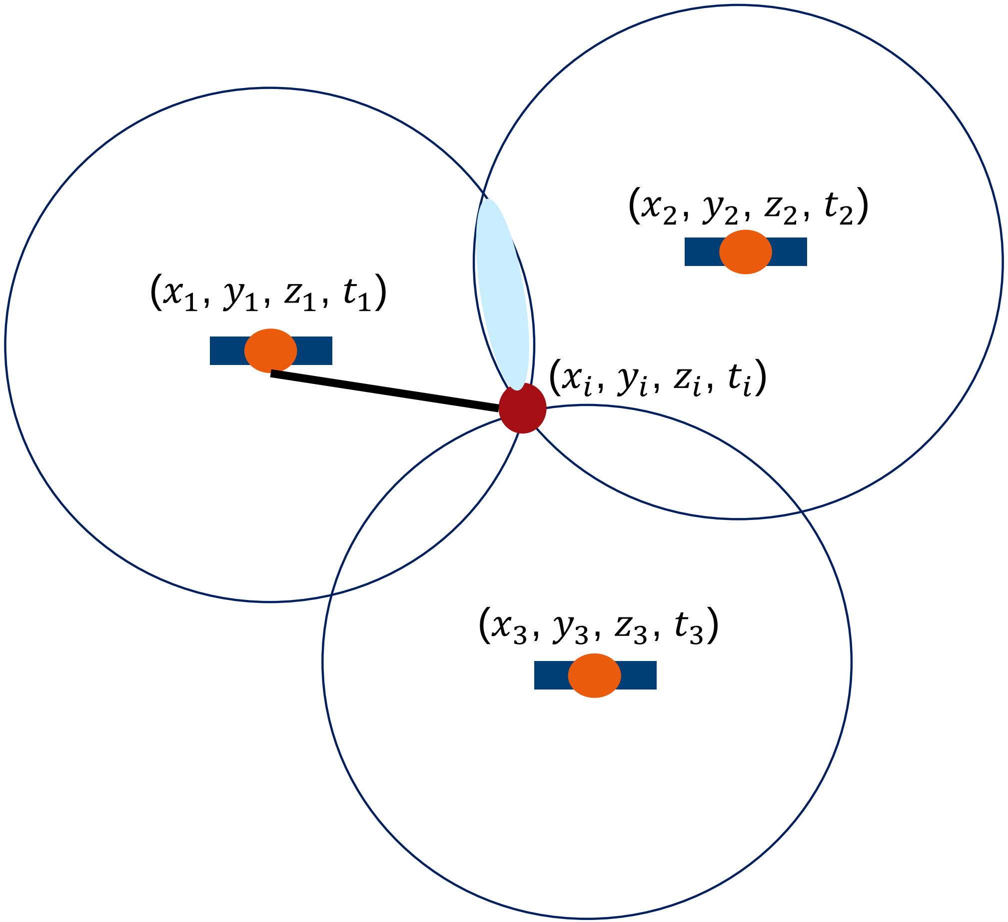
WHERE ARE YOU?



HOW TO POSITION?

$$S_1 = c \times \Delta t = c \times (t_1 - t_i)$$

$$S_1 = \sqrt{(x_1 - x_i)^2 + (y_1 - y_i)^2 + (z_1 - z_i)^2}$$



1 reference point place on a sphere
2 reference points place on a circle
3 reference points place at a spot

4 UNKNOWN VALUES, AT LEAST 4 EQUATIONS!

$$S_1 = c \times \Delta t = \mathrm{c} \times (t_1 - t_i)$$

$$S_1 = \sqrt{(x_1 - x_i)^2 + (y_1 - y_i)^2 + (z_1 - z_i)^2}$$

$$S_2 = c \times \Delta t = \mathrm{c} \times (t_2 - t_i)$$

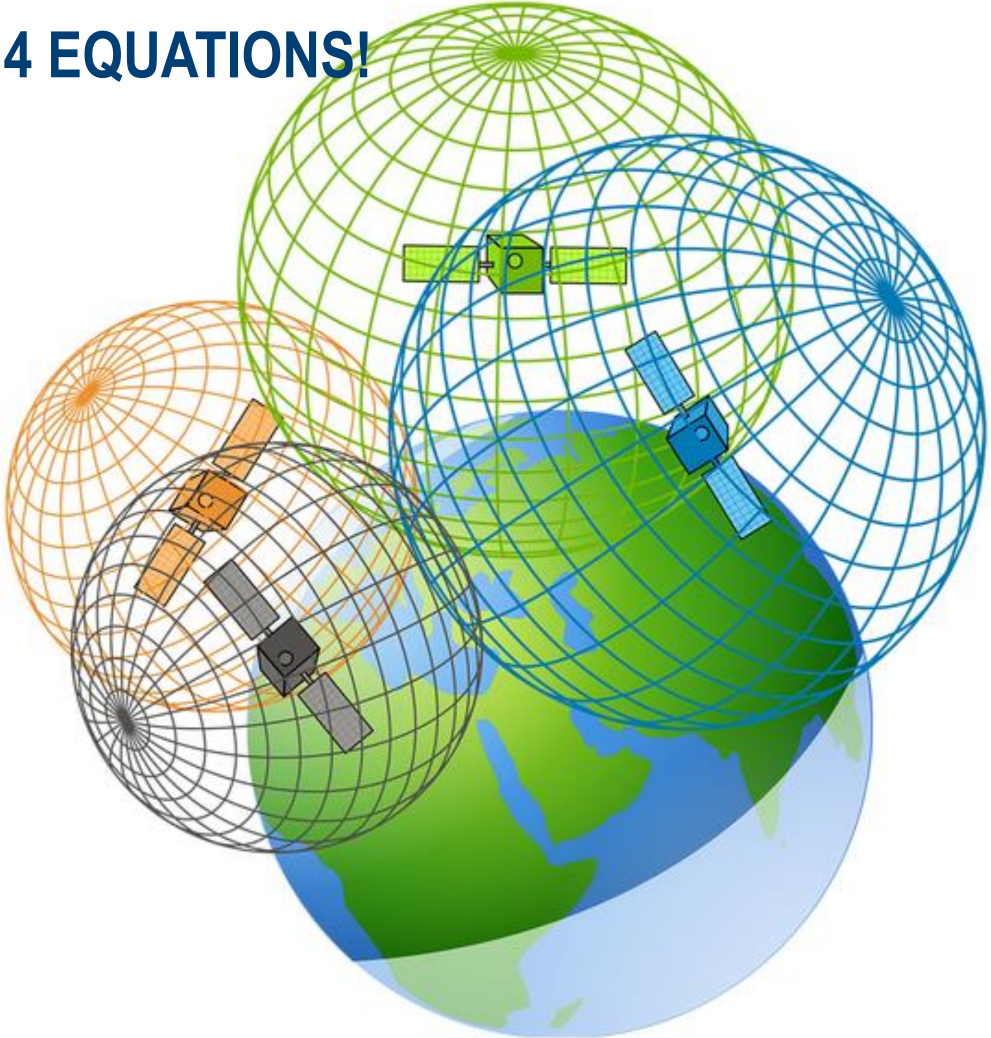
$$S_2 = \sqrt{(x_2 - x_i)^2 + (y_2 - y_i)^2 + (z_2 - z_i)^2}$$

$$S_3 = c \times \Delta t = \mathrm{c} \times (t_3 - t_i)$$

$$S_3 = \sqrt{(x_3 - x_i)^2 + (y_3 - y_i)^2 + (z_3 - z_i)^2}$$

$$S_4 = c \times \Delta t = \mathrm{c} \times (t_4 - t_i)$$

$$S_4 = \sqrt{(x_4 - x_i)^2 + (y_4 - y_i)^2 + (z_4 - z_i)^2}$$



CLOCK, TIME.

Even very small time shifts can cause long-distance position errors.

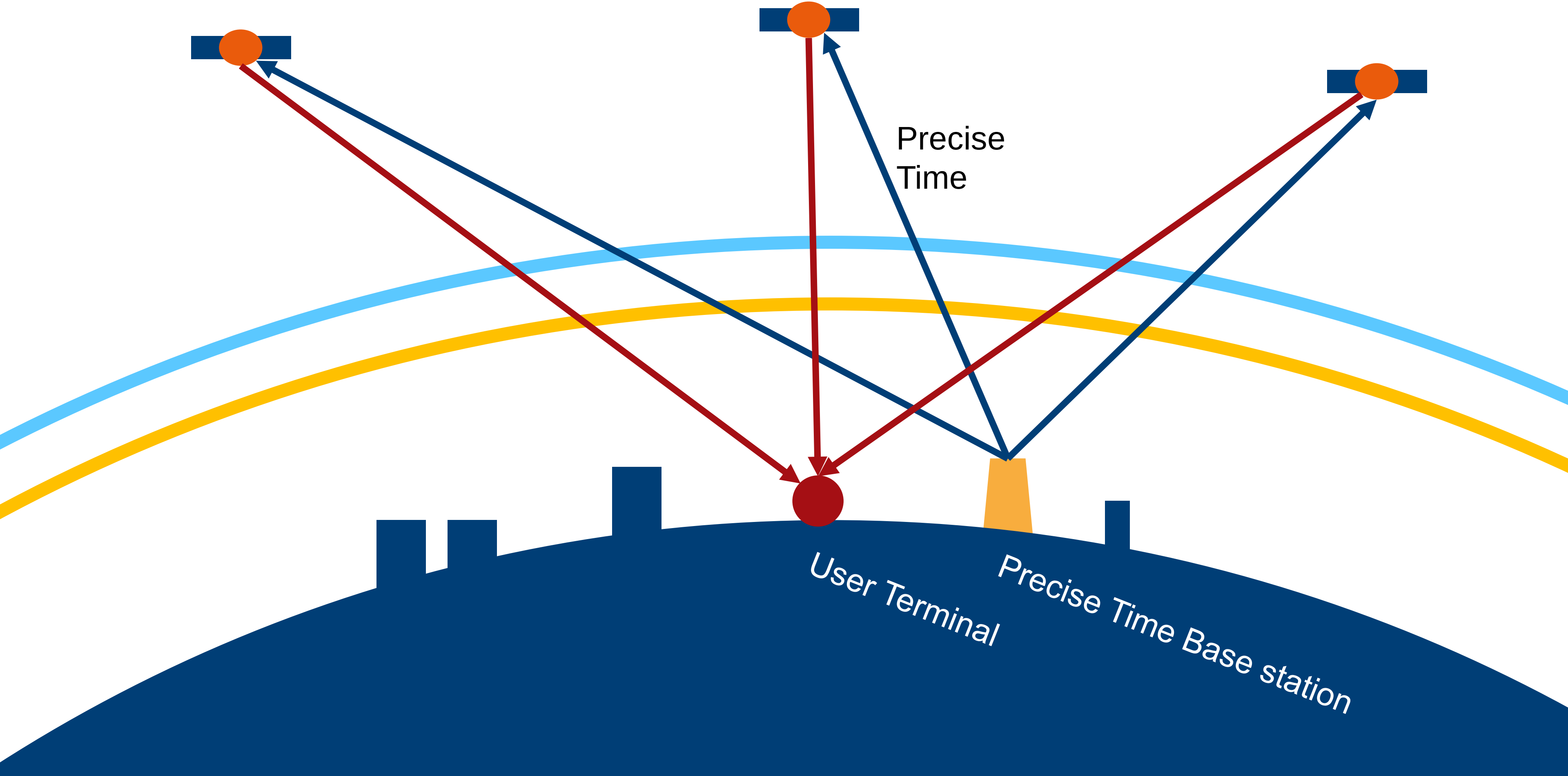
$$C=299792458\ m/s$$

$$S = c \times \Delta t$$

$$if\ \Delta t\ error = 1\mu s \ldots \ldots$$

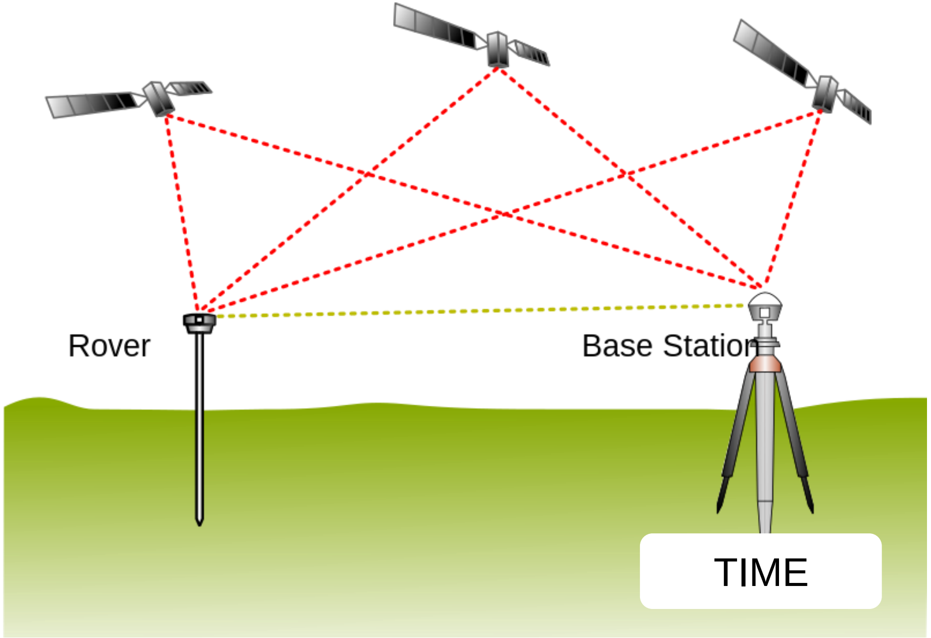
According to the theory of Relativity, the time shift on the satellite (MEO):

$$\Delta f = \frac{\mu}{C^2} \times \left(\frac{1}{R} - \frac{3}{2A}\right) \times f - \frac{2\sqrt{\mu A}}{C^2} \times e \times \sin E \times f \cong 0.51ns$$

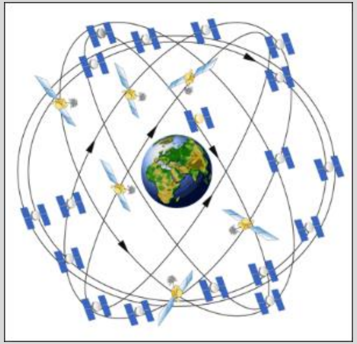

Precise
Time
User Terminal
Precise Time Base station

RTK (REAL-TIME KINEMATIC)

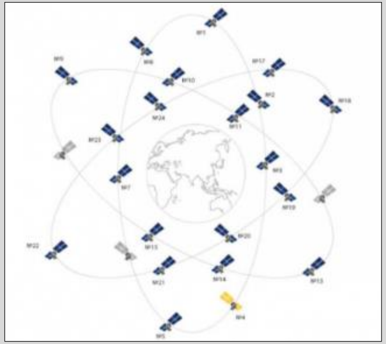
- Provide precise time to DUT directly.
- For UAVs, Drones, or Geographical Survey.
- Due to Positioning by radio (C*t), precise time is important.



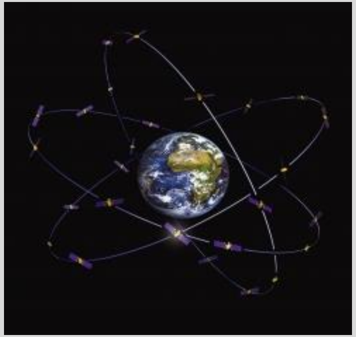
Global Systems



GPS



GLONASS



Galileo

BeiDou

QZSS/RNSS

QZSS

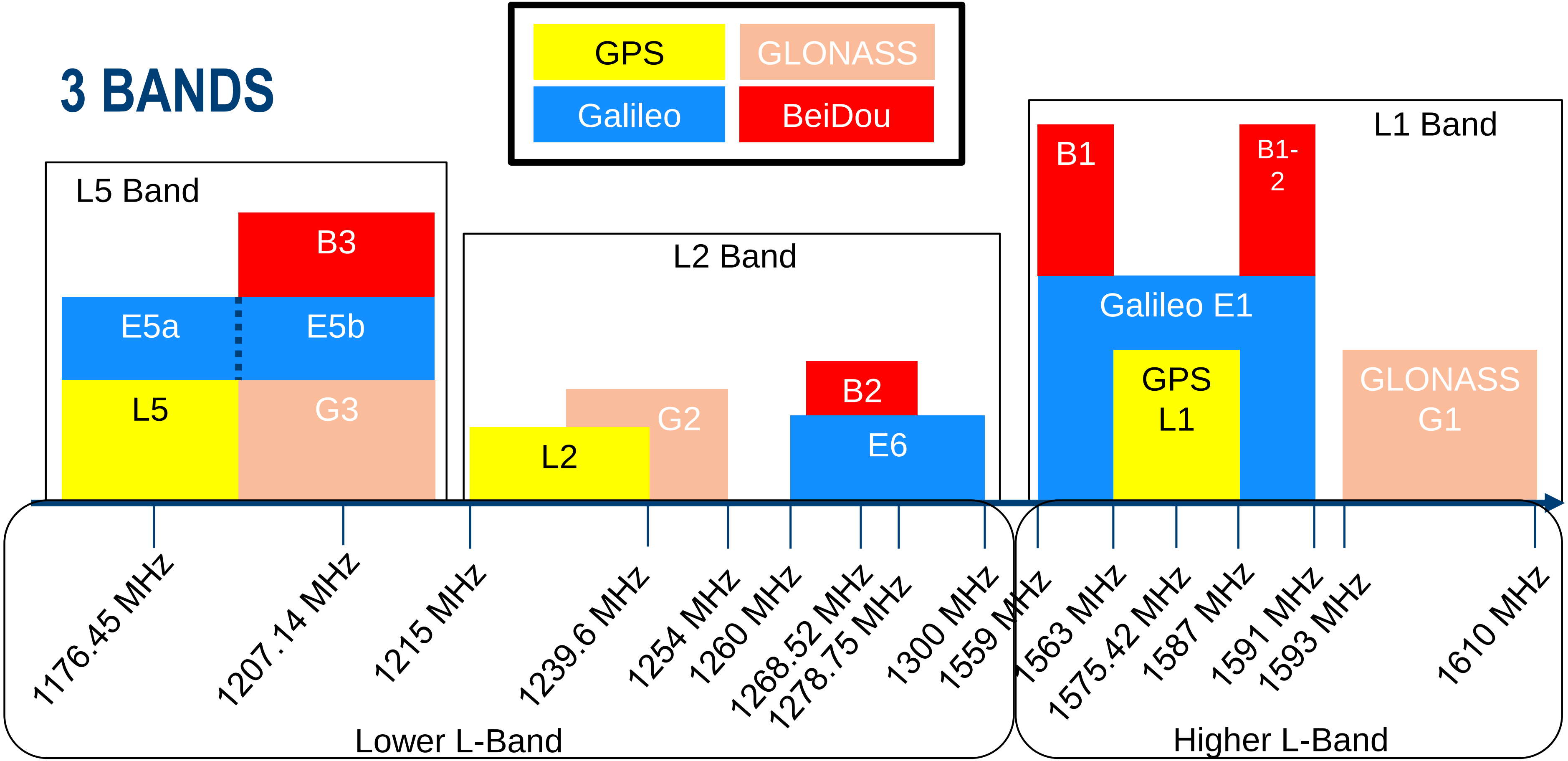
NavIC

Augmentation Systems

SBAS

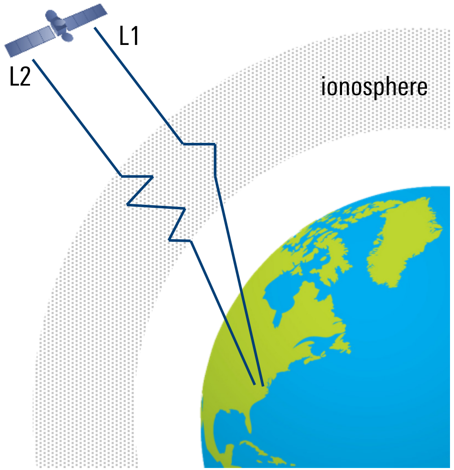
- WAAS
- EGNOS
- MSAS
- GAGAN

3 BANDS


GPS
GLONASS
Galileo
BeiDou
L5 Band
B3
E5a
E5b
L5
G3
L2 Band
G2
L2
B2
E6
L1 Band
B1
B1-2
Galileo E1
GPS L1
GLONASS G1
1176.45 MHz
1207.14 MHz
1215 MHz
1239.6 MHz
1254 MHz
1260 MHz
1268.52 MHz
1278.75 MHz
1300 MHz
1559 MHz
1563 MHz
1575.42 MHz
1587 MHz
1591 MHz
1593 MHz
1610 MHz
Lower L-Band
Higher L-Band

WHY HAVE TWO OR MORE LINK FREQUENCY?

- ► Ionospheric delay
- ► Ionospheric error
- ► Different Time Delay
- ► Greater separation between the link frequencies increases the correction accuracy
- ► Resistance to jamming
- ► Redundancy

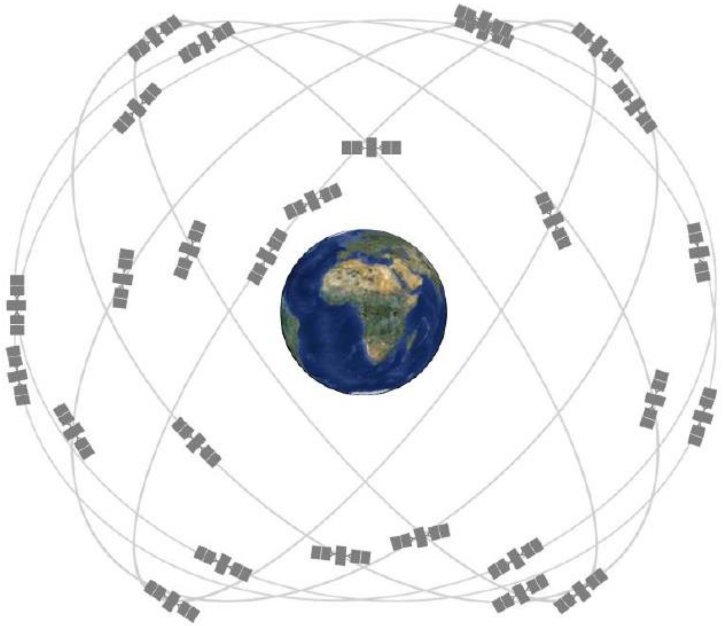


GPS (GLOBAL POSITIONING SYSTEM)

- Orbital Period : 20200 KM
- Orbital Period : 11H 58Min
- Inclination : 55°
- MEO

GPS Signal Plan

Service Name	C/A	P(Y)	L1C	L2C	M Code	L5I, L5Q
Frequency Band	L1	L1, L2	L1	L2	L1, L2	L5
Center Frequency (MHz)	1575.42	1575.42 1227.6	1575.42	1227.6	1575.42 1227.6	1176.45
Modulation	BPSK	BPSK	TMBOC	BPSK	BOC	QPSK
Code Frequency	1.023	10.23	1.023	0.5115	5.115	10.23

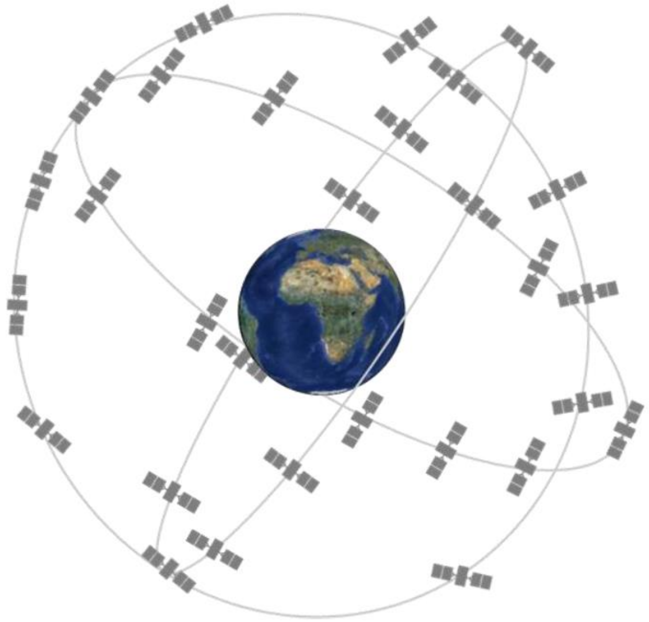


GALILEO

- Orbital Period : 23222 KM
- Orbital Period : 14H
- Inclination : 56°
- MEO

Galileo Signal Plan

Service Name	E1 OS	E1 PRS E6 PRS	E5a, E5b	E6
Frequency Band	E1	E1, E6	E5	E6
Center Frequency (MHz)	1575.42	1575.42 1278.75	1176.45 1207.14	1278.75
Modulation	CBOC	BOC	AltBOC	BPSK
Code Frequency	1.023	2.5575 5.115	10.23	5.115

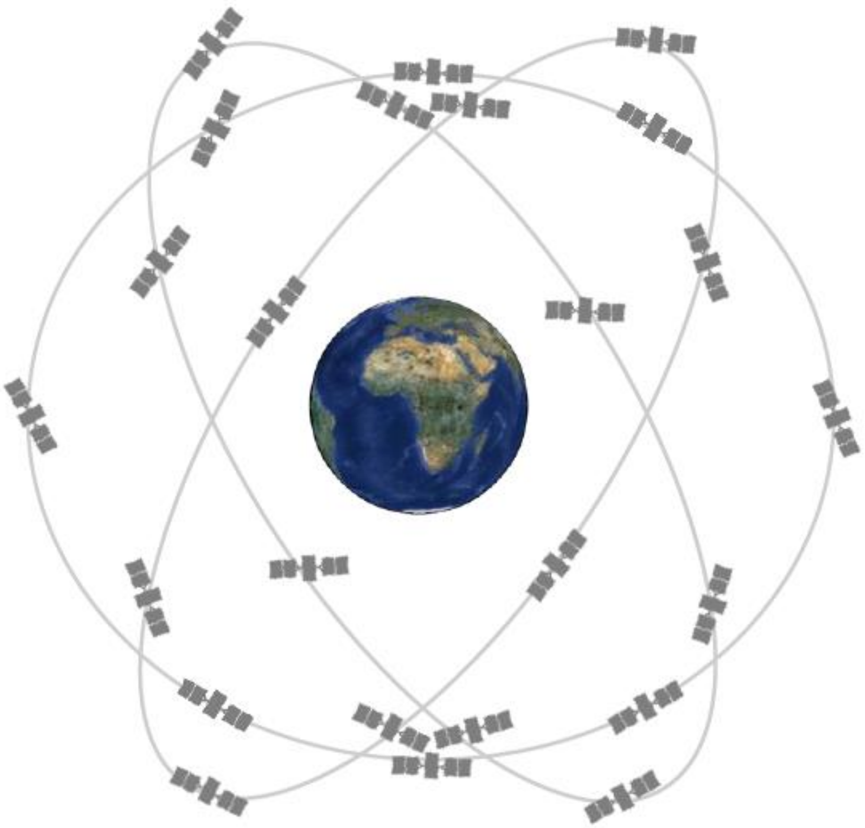


GLONASS

- ▶ Orbital Period : 19150 KM
- ▶ Orbital Period : 11H 16min
- ▶ Inclination : 64.8°
- ▶ MEO

GLONASS Signal Plan

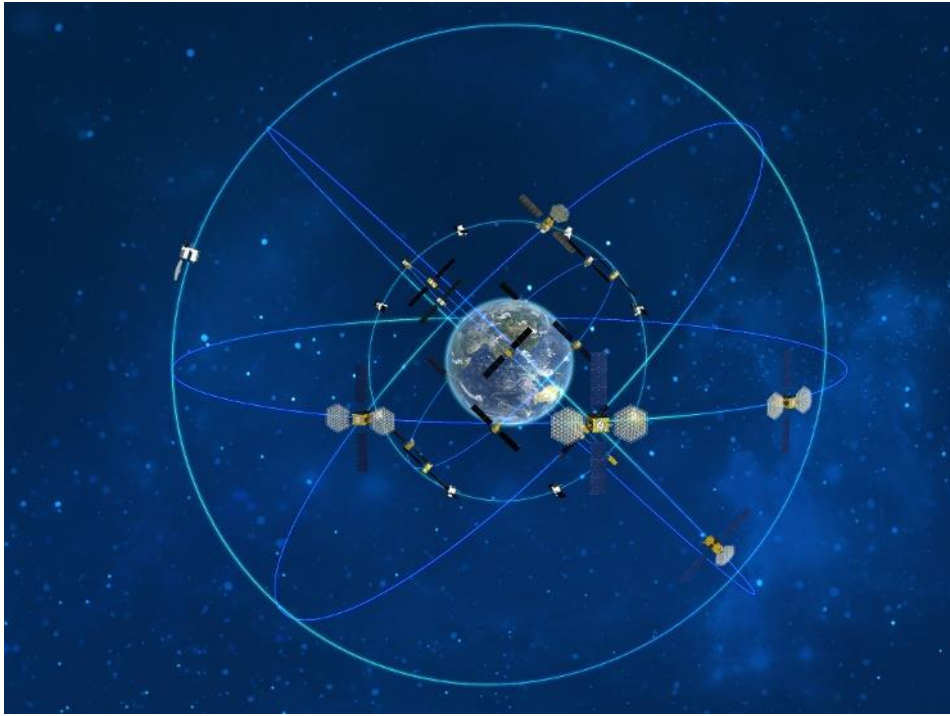
Service Name	C/A	P	G3I, G3Q
Frequency Band	G1, G2	G1, G2	G3
Center Frequency (MHz)	1602 1246	1602 1246	1202.025
Modulation	BPSK	BPSD	QPSK
Code Frequency	0.511	5.11	1.023



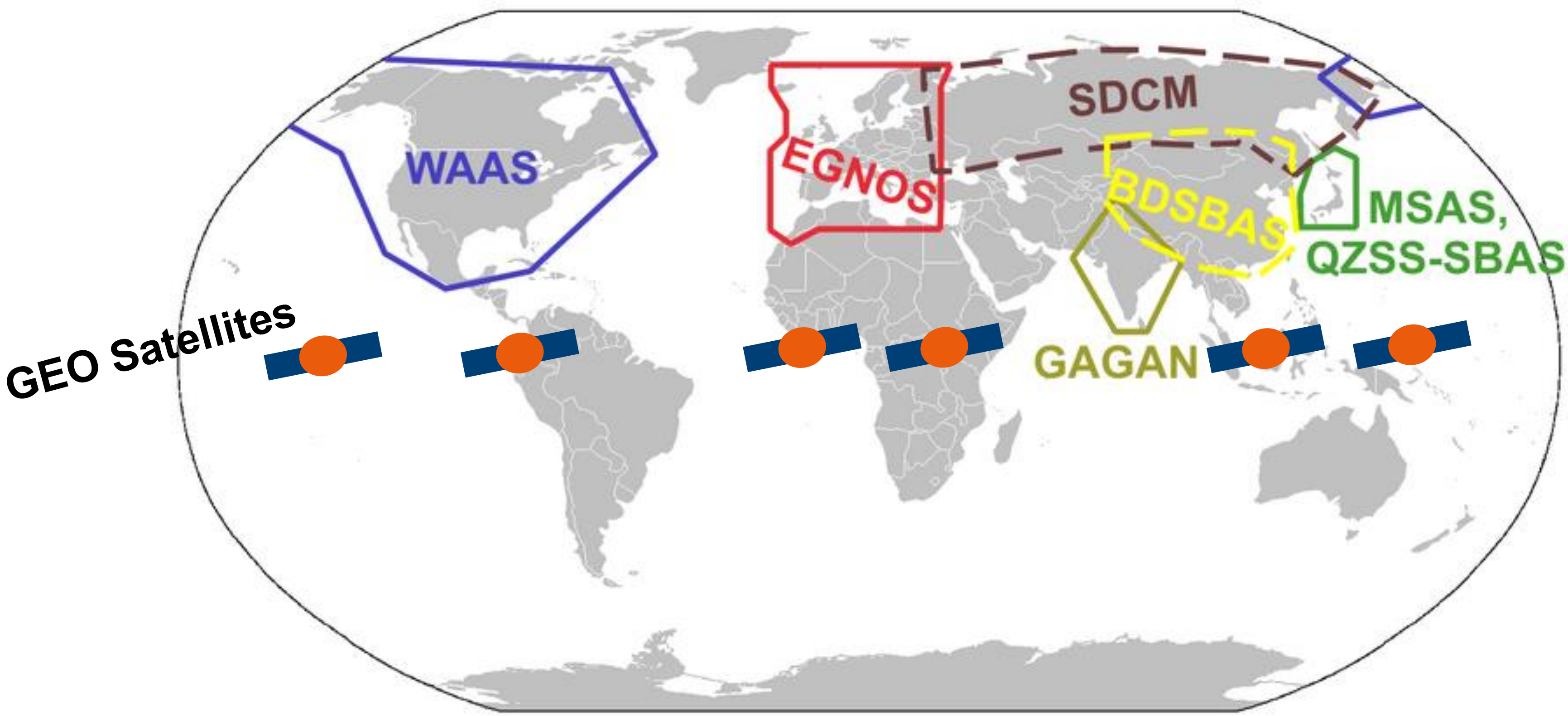
BEIDOU (北斗)

- Orbital Period : 19150 KM
- Orbital Period : 11H 16min
- Inclination : 55°
- MEO, GEO, IGSO

BeiDou Signal Plan					
Service Name	B1C	B1I	B2a	B2I	B3I
Frequency Band	L1 (B1)	L1 (B1)	L5 (B2)	L2 (B3)	L2 (B3)
Center Frequency (MHz)	1575.42	1561.098	1176.45	1207.14	1268.52
Modulation	BOC QMBOC	BPSK	BPSK	BPSK	BPSK



SBAS (SATELLITE-BASED AUGMENTATION SYSTEM)



SBAS (SATELLITE-BASED AUGMENTATION SYSTEM)

Wide Area Augmentation System
(WAAS)

Northern America

European Geostationary Navigation Overlay Service
(EGNOS)

European Unit (EU)

Multi-functional Satellite Augmentation System
(MSAS)

Japan

GPS-aided GEO augmented navigation
(GAGAN)

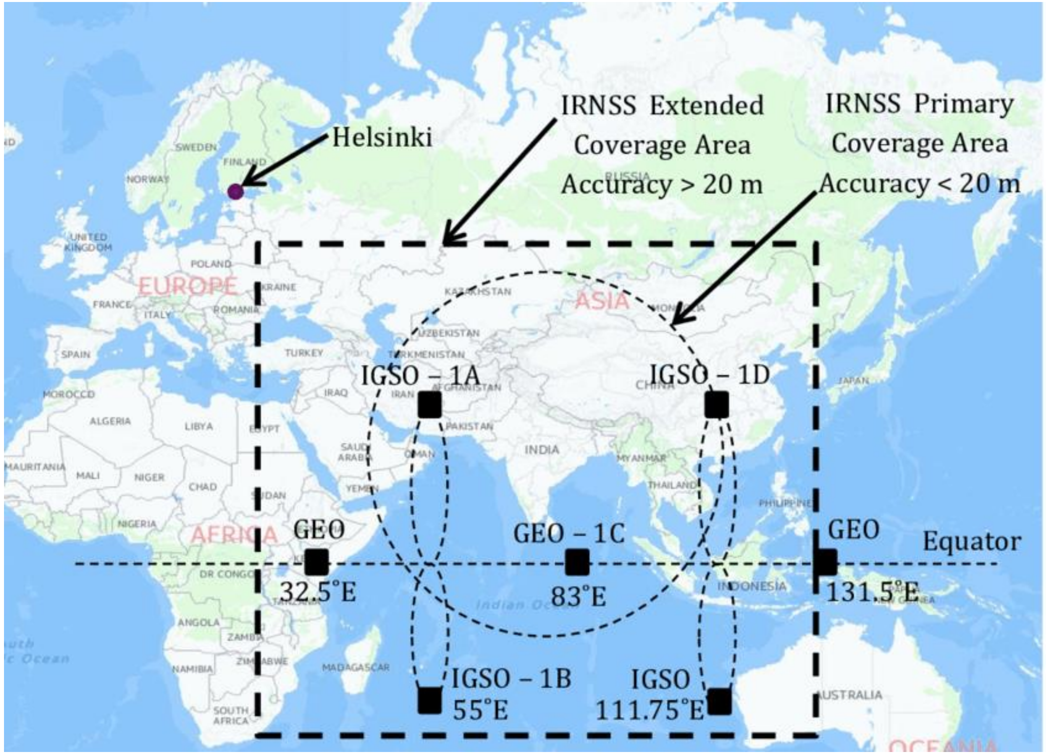
India

QZSS (QUASI-ZENITH SATELLITE SYSTEM)

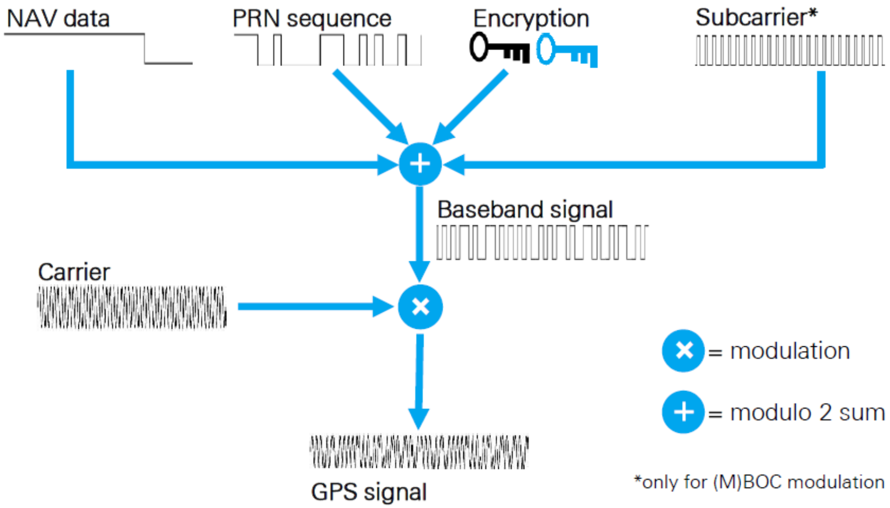
- Also knows as Michibiki (みちびき)
- Inclination : 43° ± 4°
- Longitude : 135° E ± 5°
- IGSO

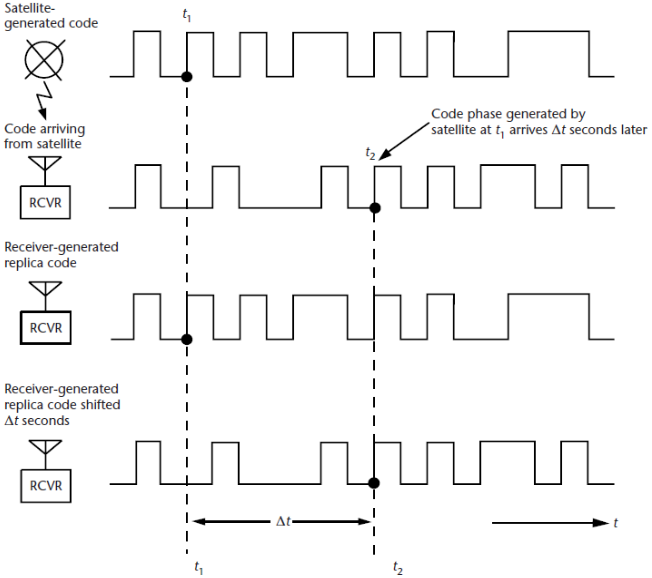
IRNSS (INDIAN REGIONAL NAVIGATION SATELLITE SYSTEM) NAVIC (NAVIGATION WITH INDIAN CONSTELLATION)

- ► GEO + IGSO
- ► Since 2018
- ► L-Band + S-Band



PRN (PSEUDORANDOM NOISE)





NMEA 0183

- NMEA also known as National Marine Electronics Association

- Receiver output files or simulate past time and path

```
$GPGGA,092750.000,5321.6802,N,00630.3372,W,1,8,1.03,61.7,M,55.2,M,,*76
$GPGSA,A,3,10,07,05,02,29,04,08,13,,,,,1.72,1.03,1.38*0A
$GPGSV,3,1,11,10,63,137,17,07,61,098,15,05,59,290,20,08,54,157,30*70
$GPGSV,3,2,11,02,39,223,19,13,28,070,17,26,23,252,,04,14,186,14*79
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$GPGSV,3,2,11,02,39,223,16,13,28,070,17,26,23,252,,04,14,186,15*77
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```
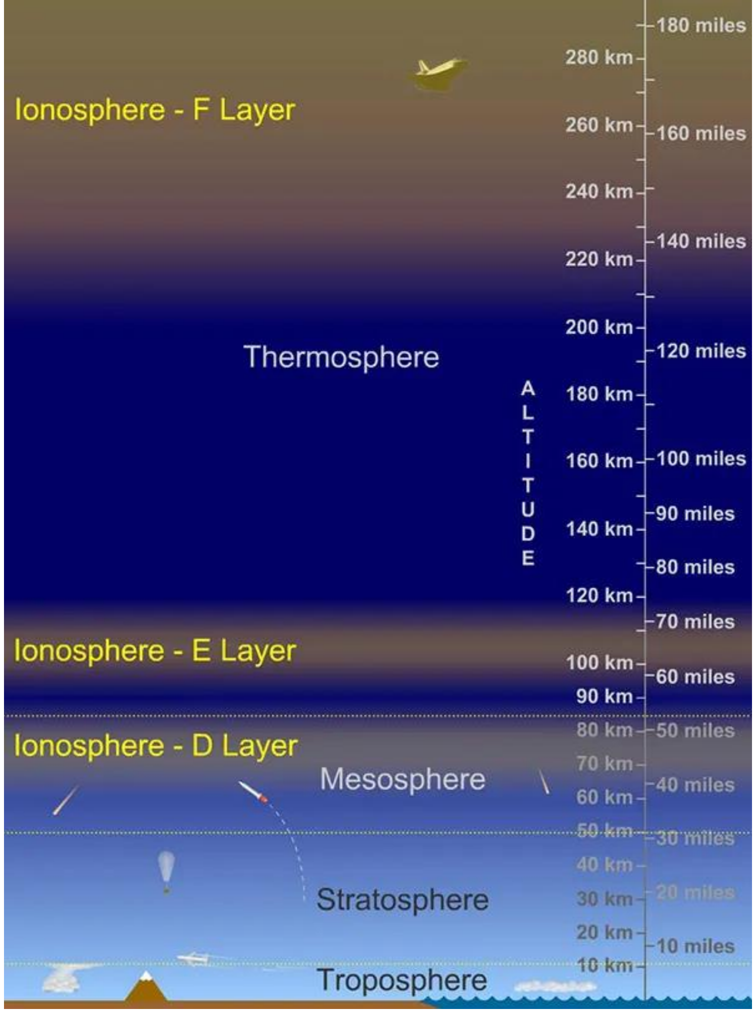

ATMOSPHERE

- Tropospheric
- Ionospheric

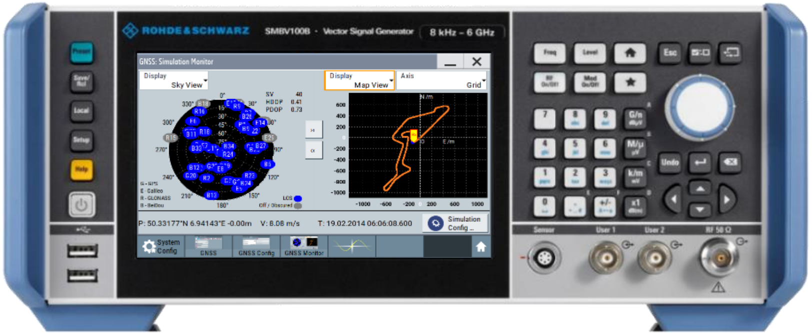


HOW DO WE GET THE GNSS SIGNAL?

HOW DO WE SIMULATE THE GNSS SIGNAL?

VECTOR SIGNAL GENERATOR

R&S SMW200A

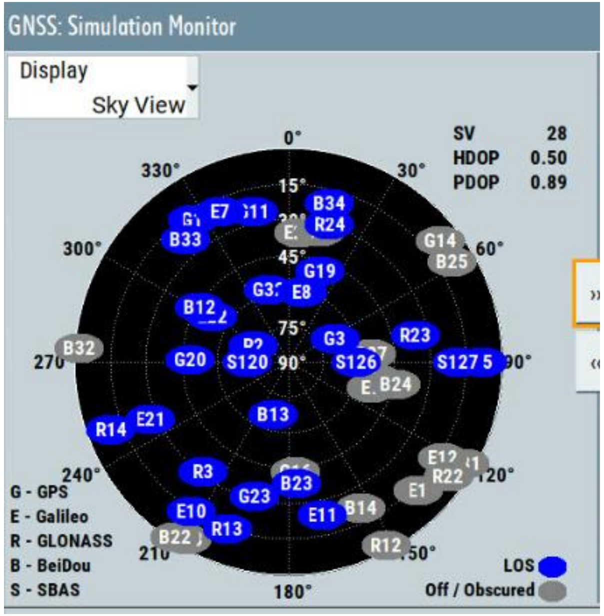


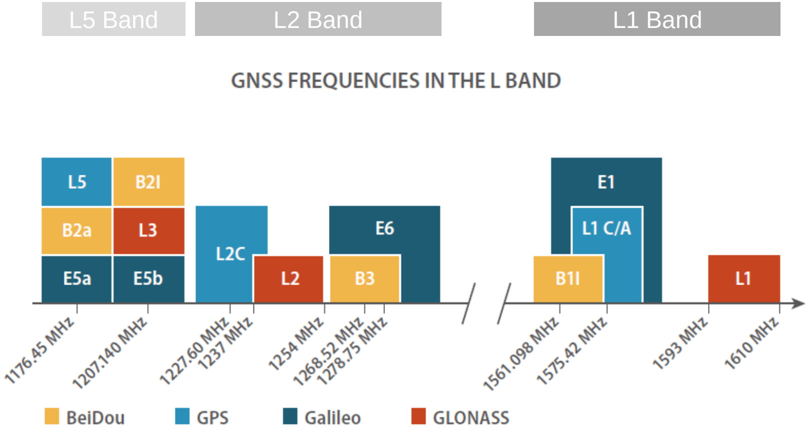
R&S SMBV100B

MULTI-CONSTELLATION, MULTI-FREQUENCY

More than one frequency band (e.g. L1 + L2)

More than one GNSS (e.g. GPS + Galileo)



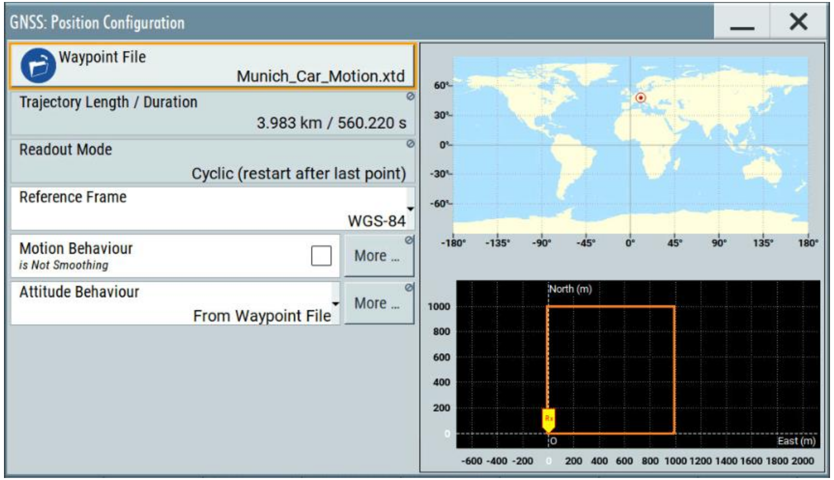


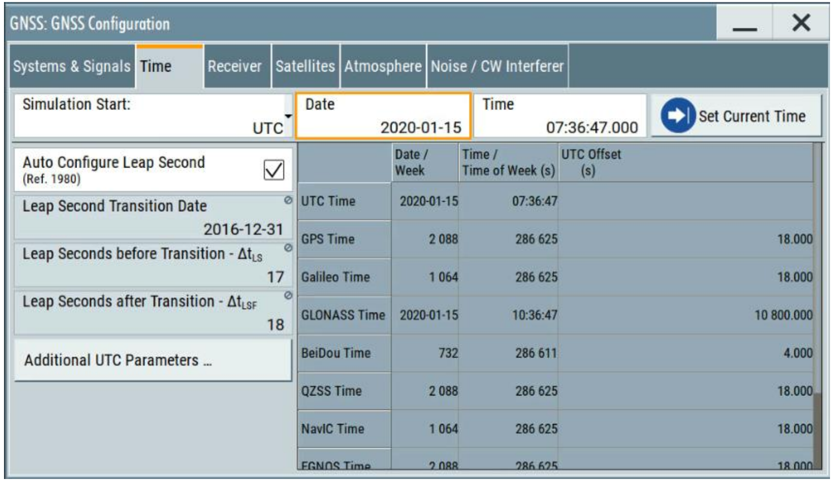
CONSTELLATIONS VS BANDS

	Constellation	L1 (E1)	L2 (E6)	L5 (E5)
GNSS	GPS	C/A, P, L1C, P(Y)-Noise, M-Noise	C/A, P, L2C, P(Y)-Noise, M-Noise	L5
	Galileo	E1 OS, E1 PRS-Noise	E6, E6PRS-Noise	E5a, E5b
	GLONASS	C/A, CDMA L1	C/A, CMDA L2	CDMA L3
	BeiDou	B1I, B1C	B3I	B2I, B2a
RNSS	QZSS	C/A, L1C	L2C	L5
	NavIC	[redacted]	[redacted]	SPS
SBAS	EGNOS	C/A	[redacted]	L5
	WAAS	C/A	[redacted]	L5
	MSAS	C/A	[redacted]	
	GAGAN	C/A	[redacted]	[redacted]

POSITION AND TIME SIMULATION

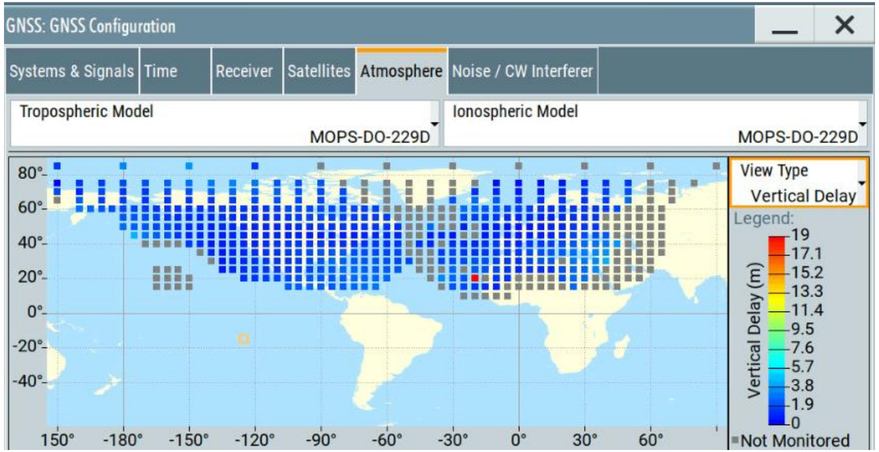
- Position
  - Static
  - Moving
  - Remote Control (HIL)
- Time
  - UTC, GPS,
  - Leap second

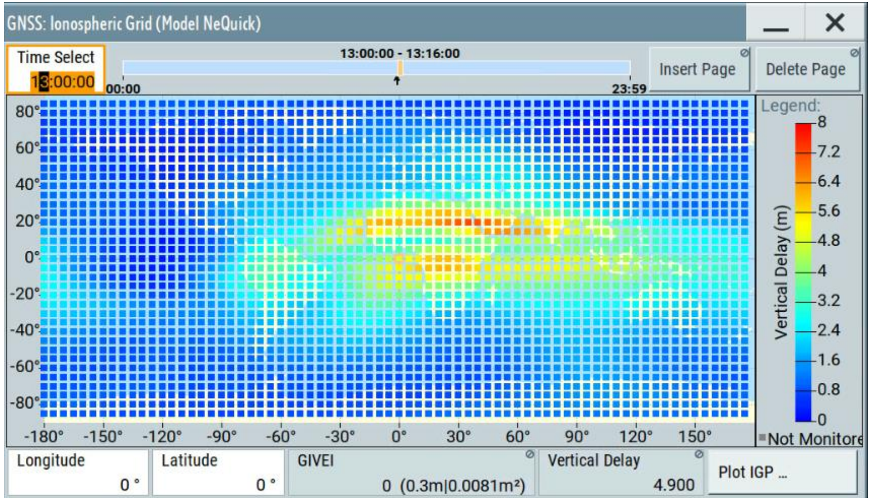




REAL-WORLD SIMULATION (ATMOSPHERE)

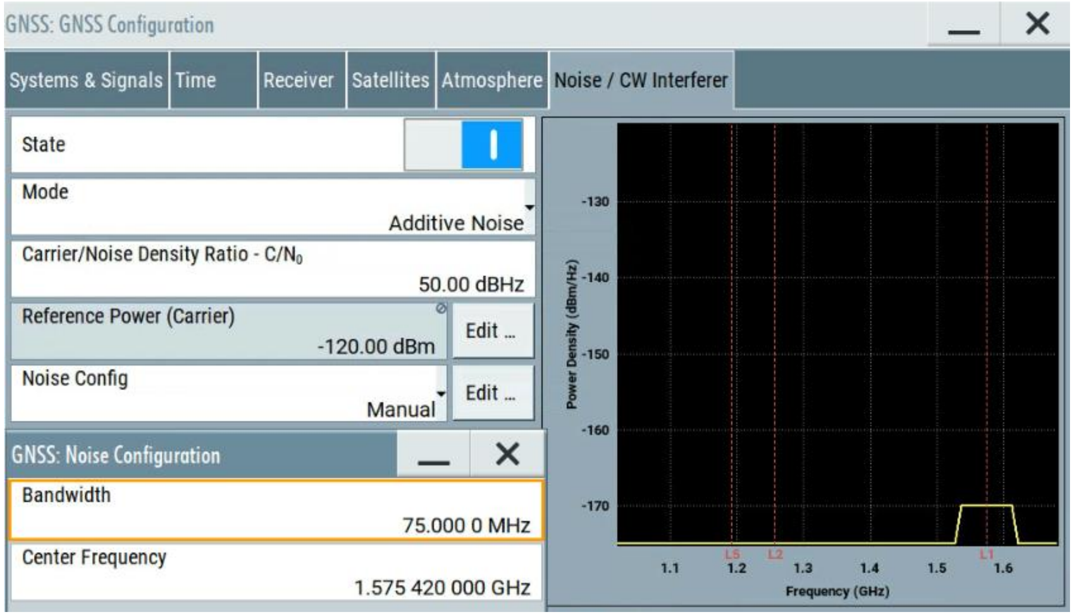
- ► Tropospheric Model
  - – STANGAG
  - – MOPS-DO-229D
- ► Ionospheric Model
  - – Klobuchar
  - – NeQuick
  - – MOPS-DO-229D





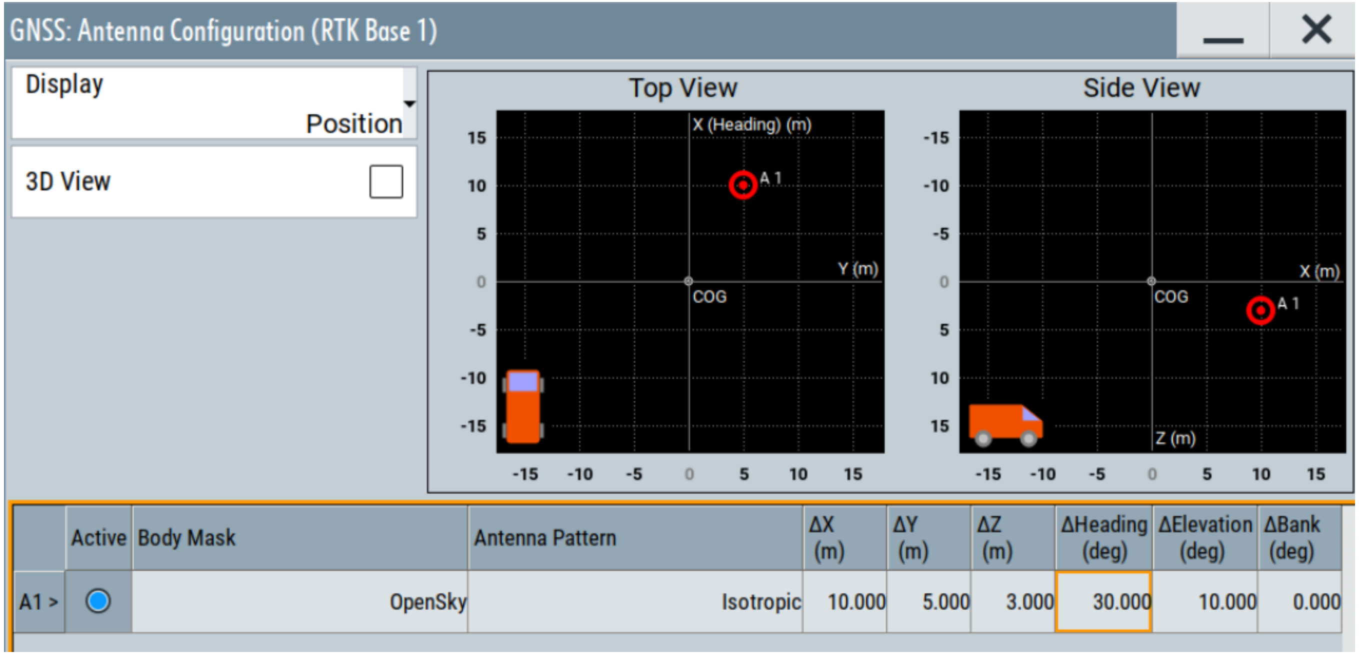
REAL-WORLD SIMULATION (NOISE/ INTERFERE)

- Noise, Interferer
  - Additive Noise
  - CW Interferer



RTK (REAL-TIME KINEMATIC)

► VSG can simulate not only GNSS but also RTK signal.



GNSS APPLICATIONS

Automotive

UAV/Drone

Cellular

LBS

GNSS OPTIONS ON VECTOR SIGNAL GENERATOR

	Option	Description
GPS	K44	GPS
	K98	Modernized GPS
	K128	P(Y)-/M-/PRS-Noise
Galileo	K66	Galileo
	K128	P(Y)-/M-/PRS-Noise
GLONASS	K94	GLONASS
	K123	Modernized GLONASS
BeiDou	K107	BeiDou
	K132	Modernized BeiDou
Augmentation	K106	SBAS/QZSS
	K97	IRNSS(NavIC)
Simulation Capacity (Frequency, Channel)	K134	Upgrade to dual-frequency
	K135	Upgrade to triple-frequency
	K136	Add 6 GNSS channels
	K137	Add 12 GNSS channels
	K138	Add 24 GNSS channels
	K139	Add 48 GNSS channels
Scenario	K108	Real world simulation
	K109	Real-time interfaces (HIL)
	K122	Real-time kinematics virtual reference station (RTK)

THANK YOU FOR YOUR ATTENTION