低軌衛星與無線通訊線上討會
-GPS於衛星之應用 APPLICATION OF GPS IN SATELLITE(GNSS)

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ROHDE&SCHWARZ
Make ideas real

AGENDA

- Overview about Satellite Positioning Systems
- How does GNSS work?
- Localization Mode vs. Generic Mode
- Which testing items we need to do for the receiver
- What is our testing solution
- Q&A

OVERVIEW

- **GPS :** Global Positioning System (GPS)_31 Satellites running in orbit, US
- **GLONASS:** Global Navigation Satellite System (GNSS), now 24 Satellites running in orbit, RUSSIA
- **Galileo:** Global Navigation Satellite system (GNSS), now 30(24) Satellites running in orbit, European Union
- **BeiDou:** BeiDou Navigation Satellite System, now 30(35) Satellites running in orbit, China
- **QZSS:** Quasi-Zenith Satellite System (QZSS) now 5(7) Satellites running in orbit, Japan

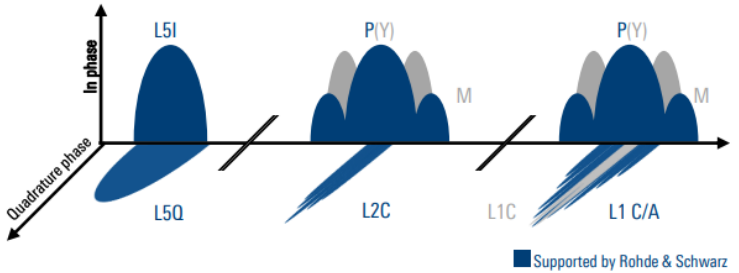
GPS STANDARD BASIC

- Operated by the United States government
- First launch in 1978
- Provides free standard positioning service (SPS) and precision positioning service (PPS) for authorized users
- 24 (plus three spare) baseline satellites; currently > 30 operational SVs
- Six orbital planes with an inclination of 55°
- Orbital altitude: ~20 200 km
- Orbital period: 11 h 58 min (half a sidereal day)
- Ground track repetition period: 23 h 56 min (one sidereal day)

GPS signal plan

Service name	C/A	P(Y)	L1C	L2CM L2CL	M-code	L5I L5Q
Frequency band	L1	L1 L2	L1	L2	L1 L2	L5
Center frequency in MHz	1575.42	1575.42 1227.6	1575.42	1227.6	1575.42 1227.6	1176.45
Modulation	BPSK(1)	BPSK(10)	TMBOC (6,1,1/11)	BPSK(1)	BOC(10,5)	QPSK(10)
Access technique	CDMA	CDMA	CDMA	CDMA	CDMA	CDMA
Code frequency in MHz	1.023	10.23	1.023	0.5115 0.5115	5.115	10.23
PRN code length	1023	$6.19 \cdot 10^{19}$	10230	10230 767250	-	10230
Data rate in bps	50	50	50	50	-	50

GPS spectrum



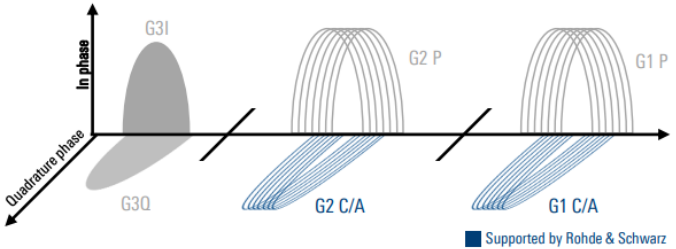
GLONASS STANDARD BASIC

- Operated by the Russian government
- First launch in 1982
- Provides free standard positioning service (ST) and precision positioning service (VT) for authorized users
- 24 baseline satellites; currently 24 operational SVs
- Three orbital planes with an inclination of 64.8°
- Orbital altitude: ~19 150 km
- Orbital period: 11 h 16 min
- Ground track repetition period: eight sidereal days

GLONASS signal plan

Service name	C/A	P	G3I G3Q
Frequency band	G1 G2	G1 G2	G3
Center frequency in MHz	1602 ± k·0.5625 1246 ± k·0.4375 k ∈ [-7,6]	1602 ± k·0.5625 1246 ± k·0.4375 k ∈ [-7,6]	1202.025
Modulation	BPSK(0.5)	BPSK(5)	QPSK(10)
Access technique	FDMA	FDMA	CDMA
Code frequency in MHz	0.511	5.11	1.023
PRN code length	511	$5.11 \cdot 10^6$	10230
Data rate in bps	50	50	100

GLONASS spectrum



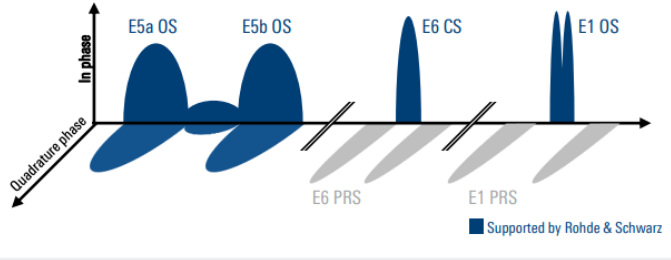
GALILEO STANDARD BASIC

- Joint initiative of the European Commission (EC), the European GNSS Agency (GSA) and the European Space Agency (ESA)
- First launch in 2011
- Provides open service (OS), public regulated service (PRS) for authorized users, commercial service (CS) and search and rescue service (SAR)
- 27 (plus three spare) baseline satellites; currently 22 operational SVs
- Three orbital planes with an inclination of 56°
- Orbital altitude: ~23 222 km Orbital period: ~14 h
- Ground track repetition period: 10 sidereal days

Galileo signal plan

Service name	E1 OS	PRS	E5a OS E5b OS	E6 CS
Frequency band	E1	E1 E6	E5	E6
Center frequency in MHz	1575.42	1575.42 1278.75	1176.45 1207.14	1278.75
Modulation	CBOC(6,1,1/11)	BOC(15,2.5) BOC(10,5)	AltBOC(15,10)	BPSK(5)
Access technique	CDMA	CDMA	CDMA	CDMA
Subcarrier frequency in MHz	6.138, 1.023	15.345 10.23	15.345	–
Code frequency in MHz	1.023	2.5575 5.115	10.23	5.115
Primary PRN code length	4092	–	10230	5115

Galileo spectrum



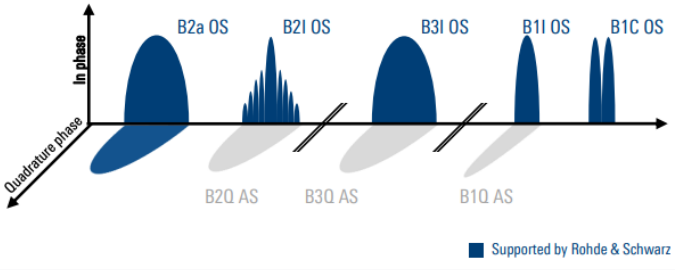
BEIDOU STANDARD BASIC

- Chinese GNSS, managed by the China Satellite Navigation Project Center (CSNPC)
- First launch in 2000
- Provides free open service (OS) and authorized service (AS)
- 30 baseline satellites (BeiDou-III); currently 29 operational SVs
- 24 MEO, 3 IGSO, 3 GEO satellites (BeiDou-III)
- MEO satellites:
  - Three orbital planes with an inclination of 55°
  - Orbital altitude: ~21 500 km
  - Orbital period: ~13h
  - Ground track repetition period: seven sidereal day

BeiDou signal plan

Service name	B1I (OS) B1Q (AS)	B1C (OS)	B2I (OS) B2Q (AS)	B2a (OS)	B3I (OS) B3Q (AS)
Frequency band	B1	B1	B2	B2	B3
Center frequency in MHz	1561.098	1575.42	1207.14	1176.45	1268.52
Modulation	BPSK(2)	BOC(1,1) QMBOC(6,1,4/33)	BPSK(2) BPSK(10)	BPSK(10)	BPSK(10)
Access technique	CDMA	CDMA	CDMA	CDMA	CDMA
Code frequency in MHz	2.046	1.023	2.046 10.23	10.23	10.23
Primary PRN code length	2046 -	10230	2046 -	10230	10230
Data rate in bps	500	100	500	200	500

BeiDou spectrum



QZSS STANDARD BASIC

- Covers East Asia and the Oceania region
- Augmentation and complementary system to GPS
- One geostationary and three geosynchronous satellites
- Outlook: extension to a standalone regional navigation satellite
- system (RNSS) with seven satellites is being carried out

QZSS signal plan

Service name	C/A	L1C [1]	SAIF [1]	L2CM, L2CL [1]	L5I, L5Q [1]	LEX [1]
Frequency band	L1	L1	L1	L2	L5	E6
Center frequency in MHz	1575.42	1575.42	1575.42	1227.6	1176.45	1278.75
Modulation	BPSK(1)	BOC(1,1)	BPSK(1)	BPSK(1)	BPSK(10)	BPSK(5)

[1] Not supported by Rohde & Schwarz instruments.

WHAT IS GPS?
GPS IS A SATELLITE NAVIGATION SYSTEM

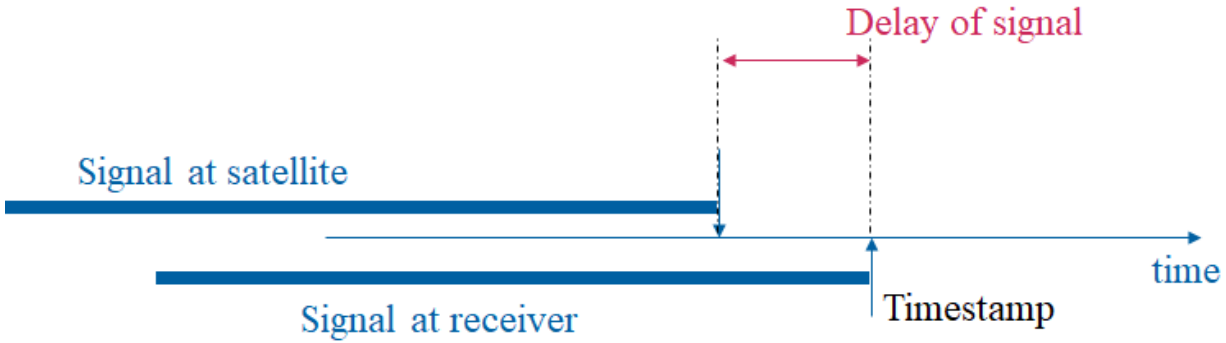
- GPS is funded and controlled by the U. S. Department of Defense (DOD). While there are many thousands of civil users of GPS world-wide, the system was designed for and is operated by the U. S. military.

- GPS provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity and time.

- Four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock.

HOW DOES GPS WORK?
SETUP OF A GPS SYSTEM

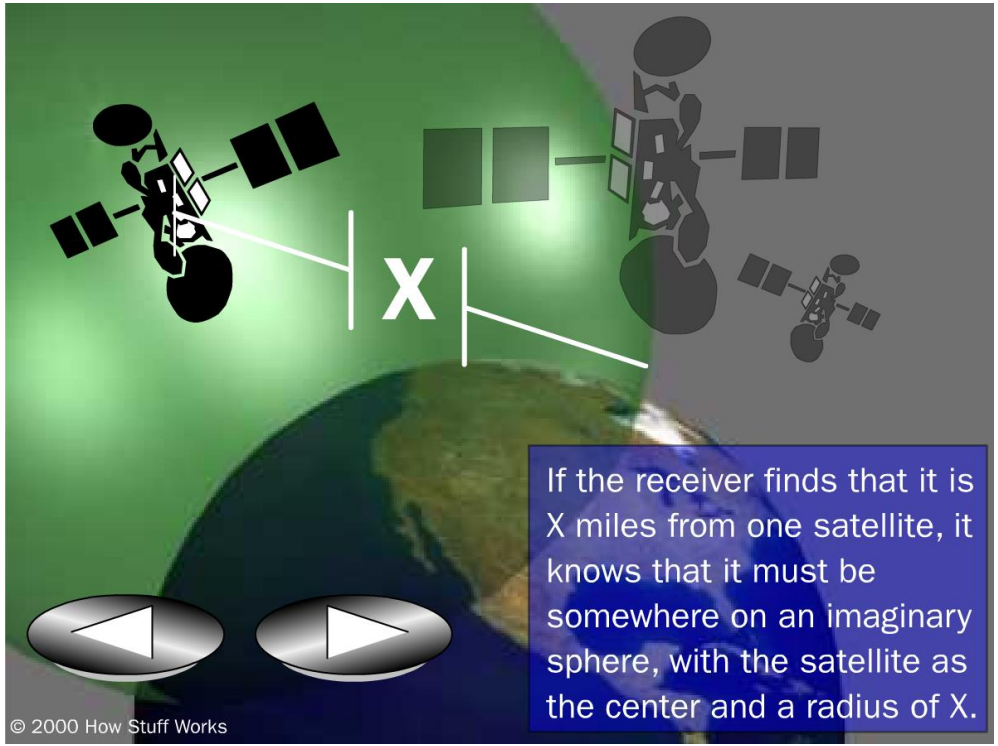
- Every satellite sends information about position and time of transmission
- Receiver analyzes signal and compares time information with own clock



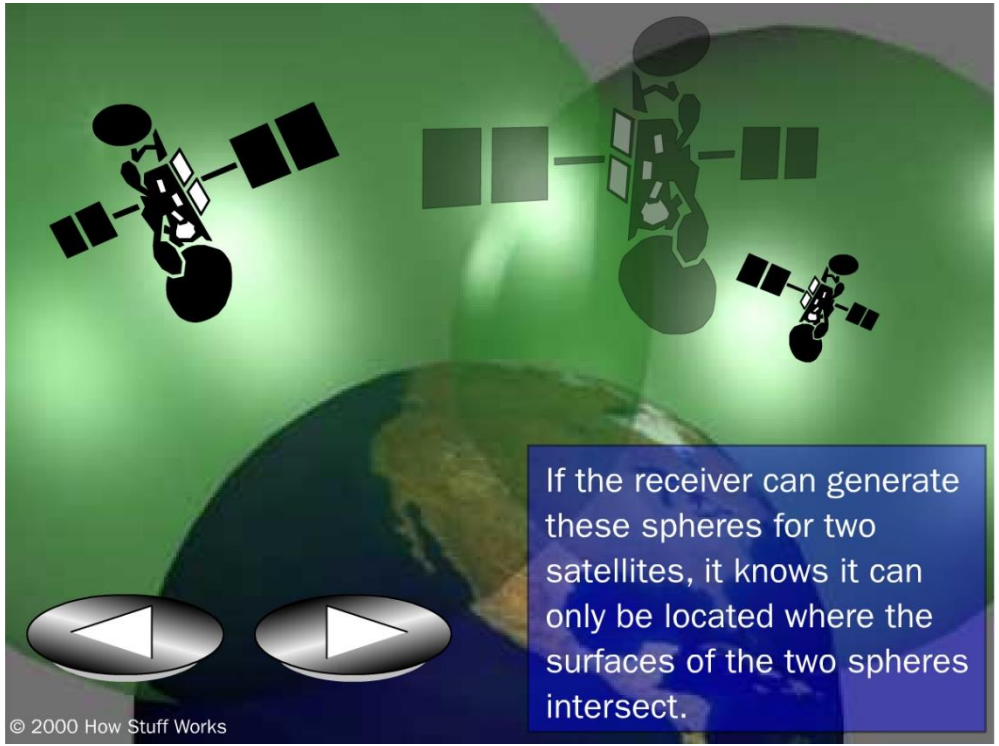
Distance to satellite = Speed of light * Delay of signal

HOW DOES GPS WORK?
TRILATERATION IN 2D

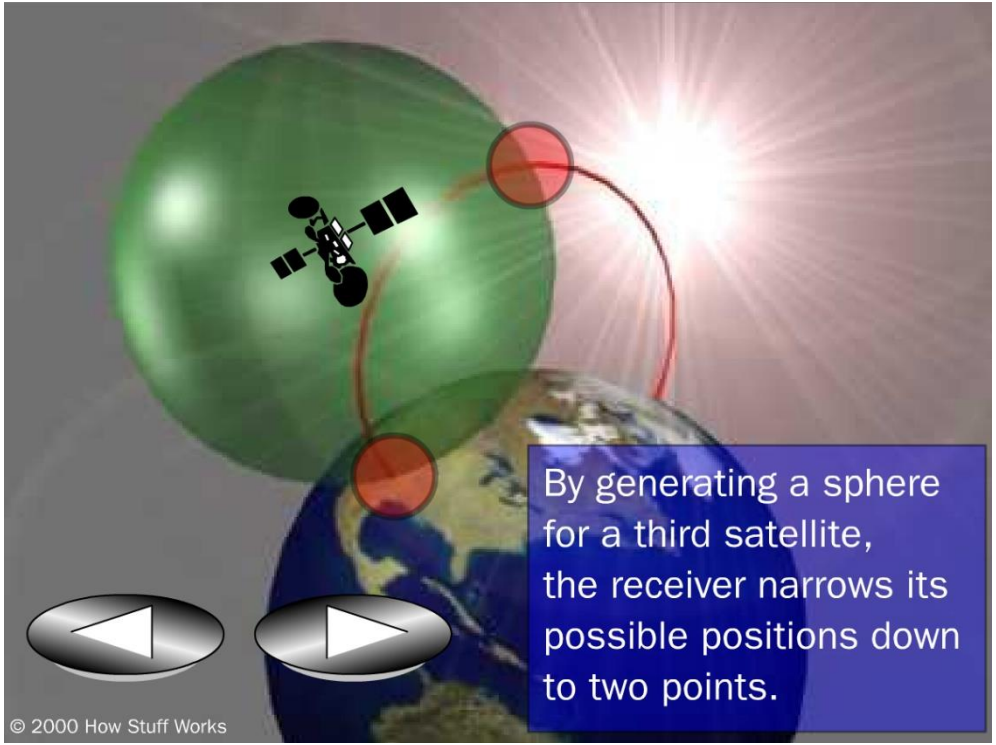
HOW DOES GPS WORK?
TRILATERATION IN 3D



HOW DOES GPS WORK?
TRILATERATION IN 3D

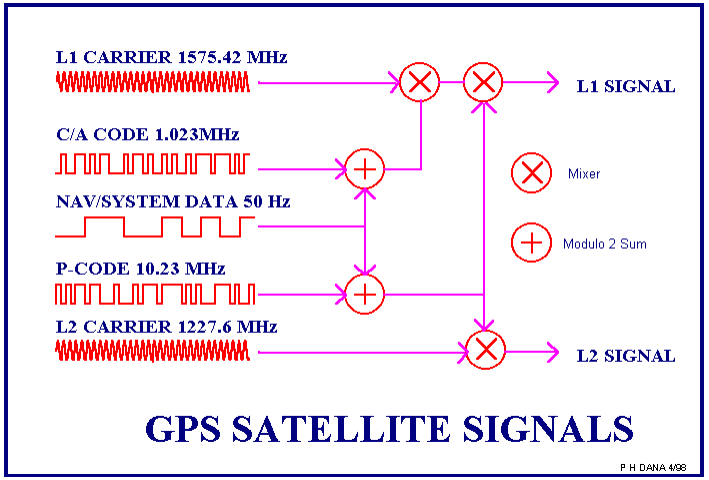


HOW DOES GPS WORK?
TRILATERATION IN 3D



HOW DOES GPS WORK
PHYSICAL SIGNALS

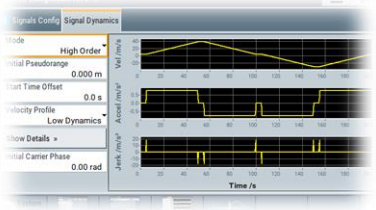
- C/A-Code and P-Code are BPSK modulated
- M-Code coming up with new sat & new frequency
- Satellites identify themselves with 37 C/A-Codes (Gold-codes)
- GPS receivers are using signal propagation delay, phase information and Doppler shift

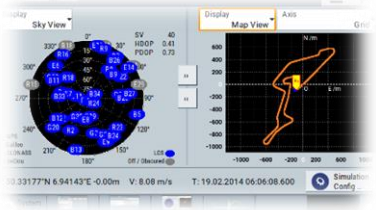


C/A: Coarse Acquisition
P: Precision

GNSS ON SMBV100B
ADDRESSED TEST APPLICATIONS

can be configured as





GNSS production tester

- Single- or multi-frequency
- GPS, GLO, GAL, BD
- L1/L2/L5
- 1 SV per system/freq.

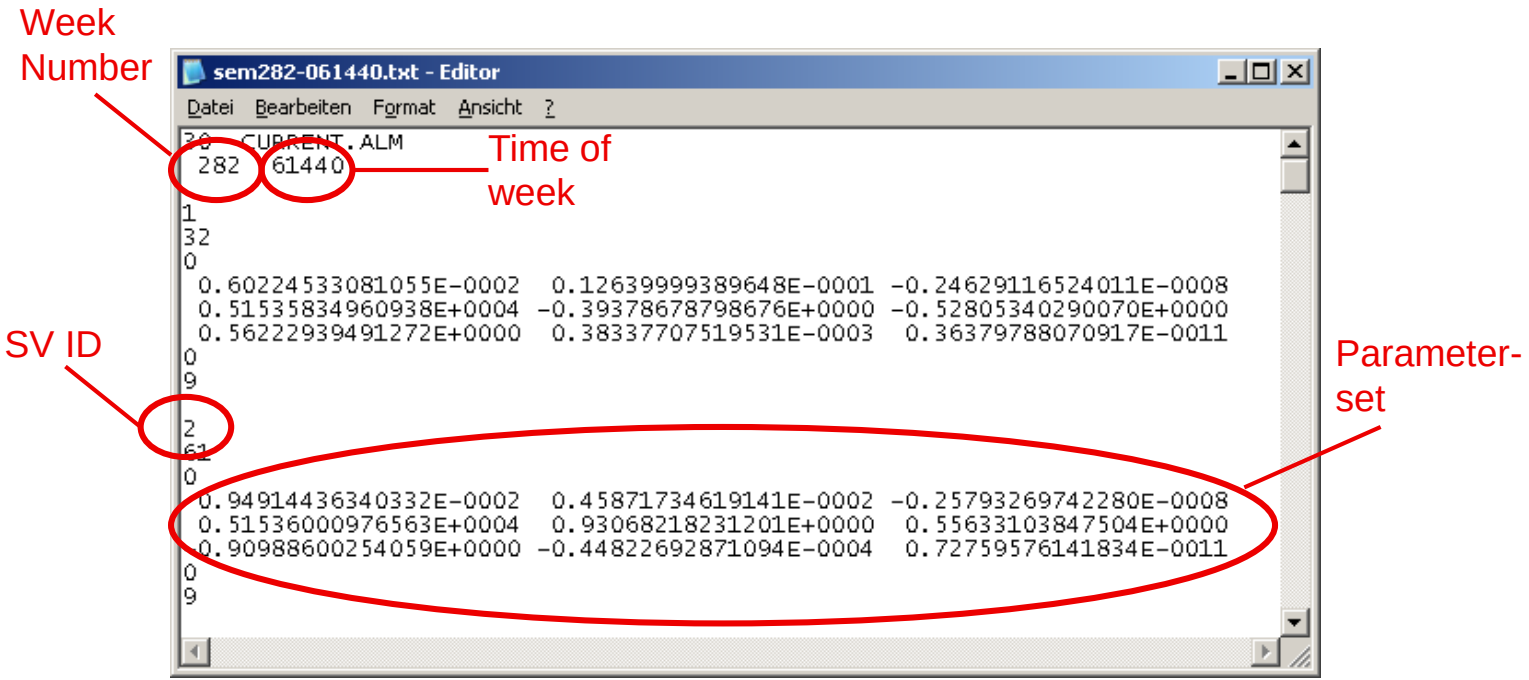
Upgrades are possible

GNSS constellation simulator

- Single- or multi-frequency
- GPS, GLO, GAL, BD, QZSS, SBAS
- L1/L2/L5
- 102 channels

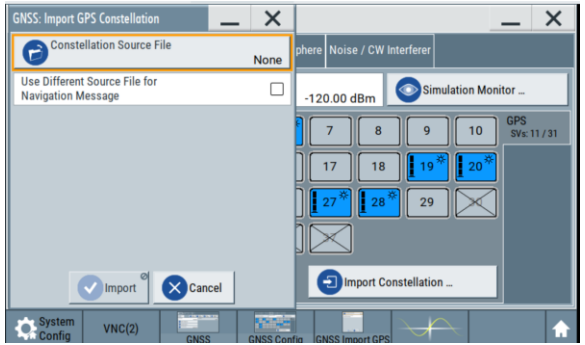
HOW DOES GPS WORK
ALMANACH

- Describing the track of each satellite



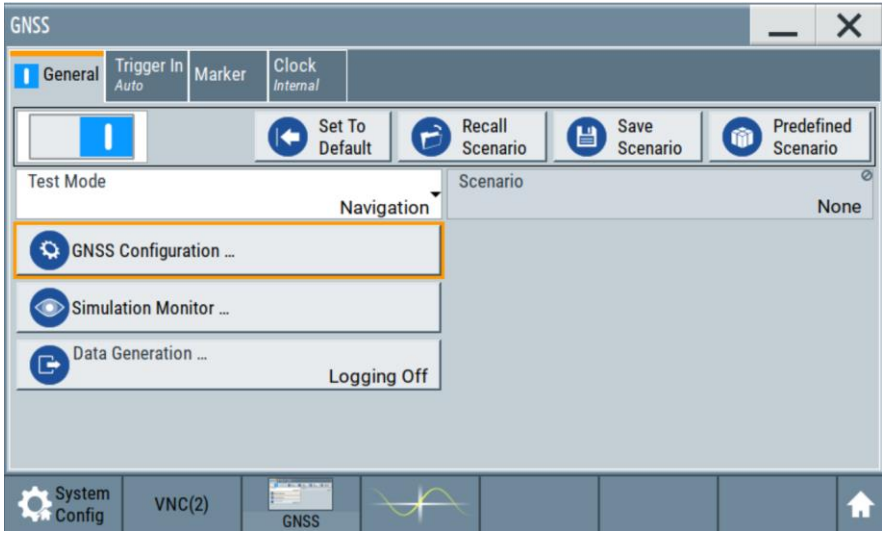
SMBV100B-K44
SIMULATION MODE

- Real Navigation Data
  - Data from Almanach
  - Almanach data is released twice a week in the internet
    e.g.
    www.celestrak.com/GPS/almanac/SEM
  - Date and time of the simulation has to be set

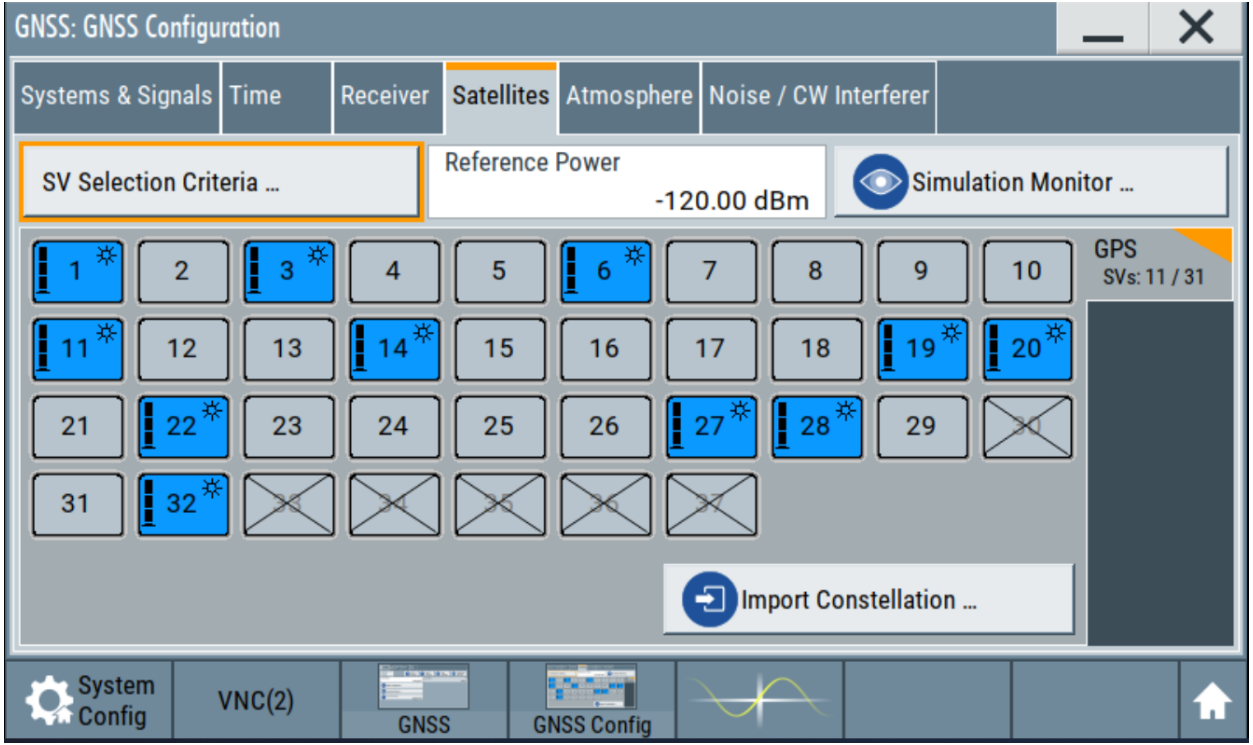


HOW MANY SATELLITES CAN BE SIMULATED?

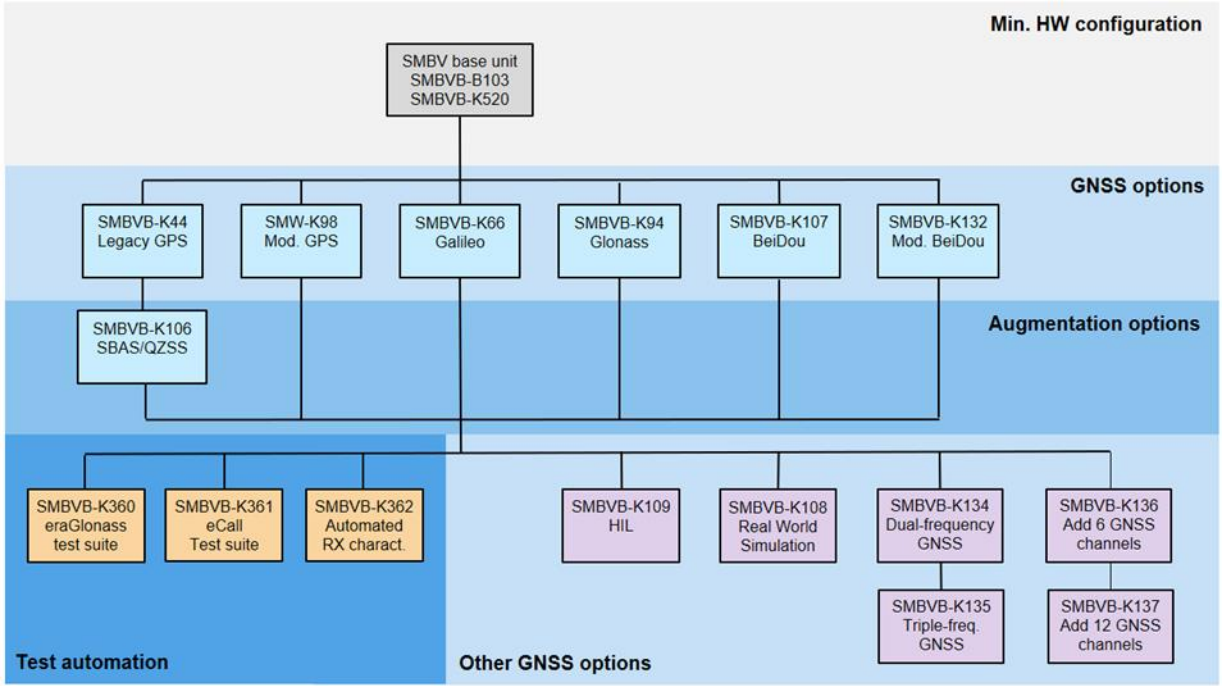
- **SMBV-K44**
- **SMW-K44**



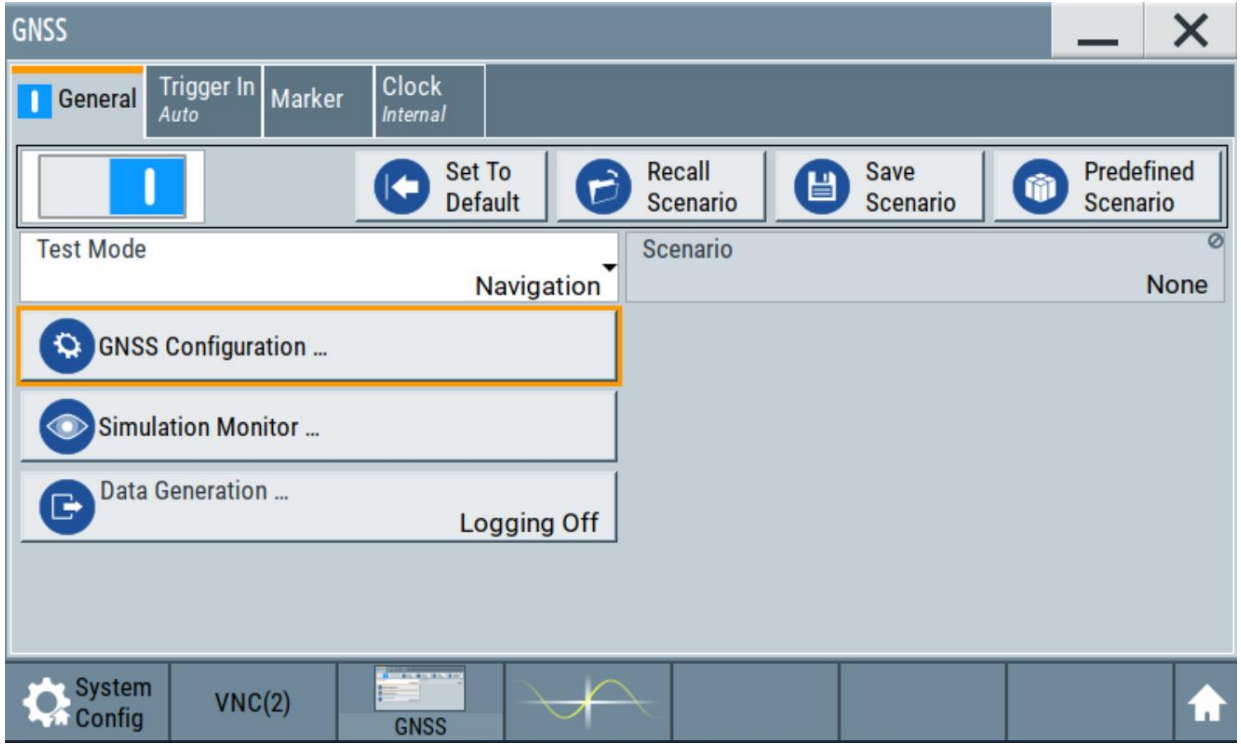
HOW MANY SATELLITES CAN BE SIMULATED?



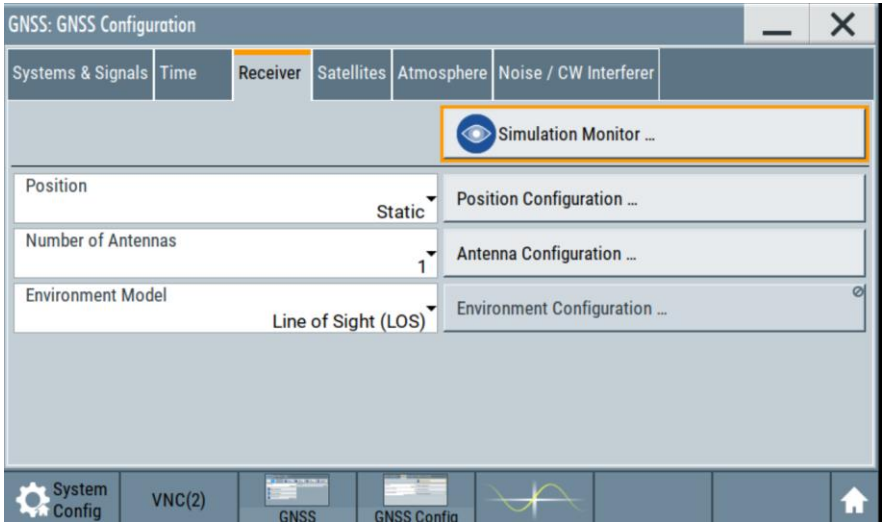
CONFIGURATION OF SMBV100B
GNSS CONSTELLATION SIMULATOR

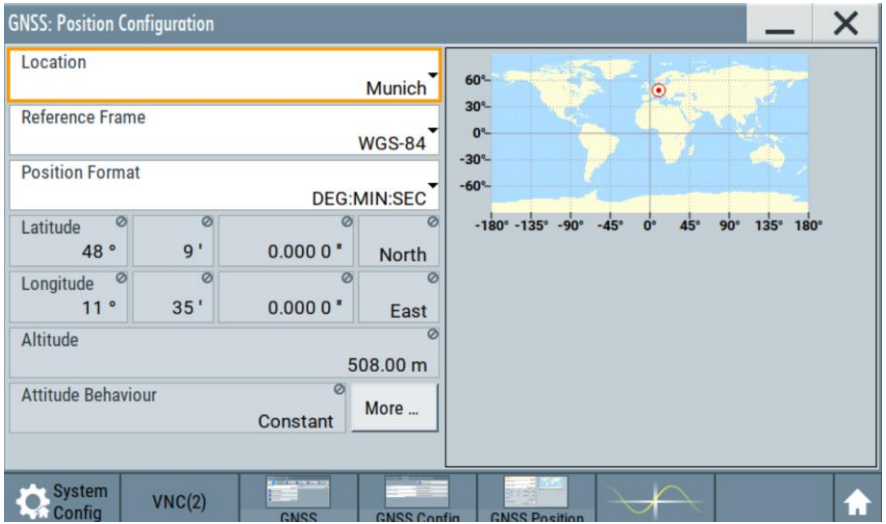


LOCALISATION MODE

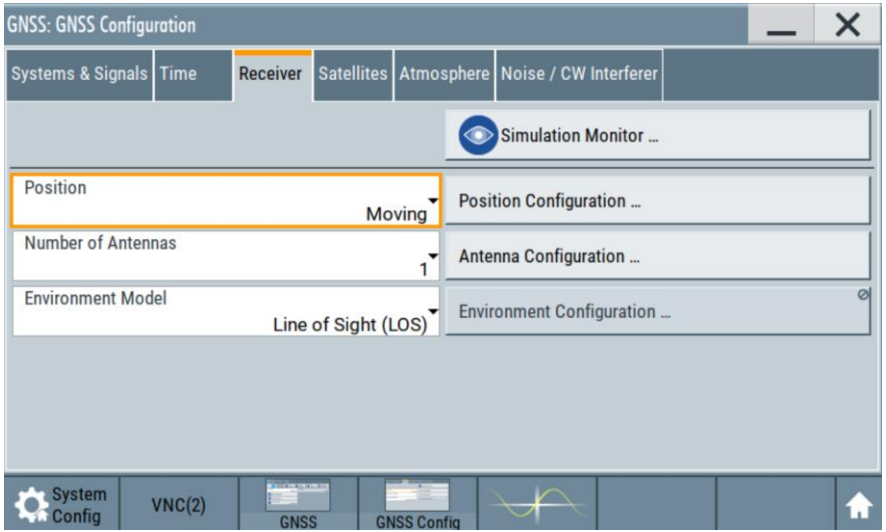


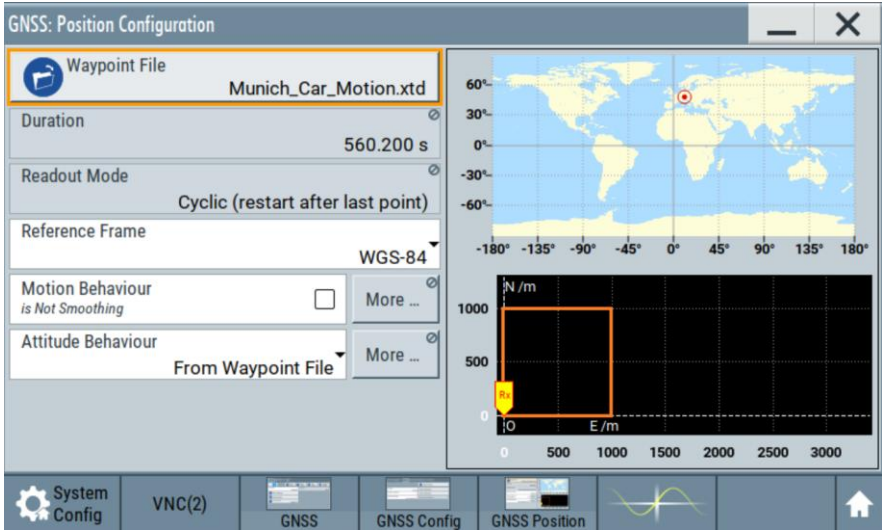
LOCALISATION MODE-STATIC





LOCALISATION MODE-MOVING





EXAMPLE FOR RECEIVERS_1

EXAMPLE FOR RECEIVERS_2

GNSS

單頻高靈敏度 GNSS	GPS+BeiDou+Galileo（亞洲地區）； GPS+GLONASS+Galileo（其他地區）
多頻多系統高精準度 RTK GNSS	使用頻率： GPS：L1/L2； GLONASS：L1/L2； BeiDou：B1/B2； Galileo：E1/E5 首次定位時間：＜50 s 定位精準度：垂直1.5 cm＋1 ppm（RMS）； 水平1 cm＋1 ppm（RMS） 1 ppm 是指飛行器每移動1 km 誤差增加1 mm

TYPICAL RECEIVER TESTS

- Time To First Fix (TTFF) under cold, warm or hot start conditions
- Location accuracy (relative and absolute location accuracy, moving location accuracy)
- Sensitivity (acquisition sensitivity, tracking sensitivity)
- Reacquisition time
- Interference testing
- Multipath testing
- Testing under varying ionospheric and tropospheric conditions

GNSS ON SMBV100B
TEST CASES COVERED BY SMBVB-K362

Test case	Performance tests	Test description
1	**Verify NMEA transmission from DUT**	Checks for compliance of the NMEA messages coming from the DUT against the NMEA specification, and detects missing or corrupts NMEA sentences.
2	**Location accuracy (static receiver)**	Measures the accuracy of the position obtained by the DUT relative to the actual (simulated, static) position.
3	**Location accuracy (moving receiver)**	Measures the accuracy of the position obtained by the DUT relative to the actual (simulated, moving) position.
4	**Time-to-first fix (TTFF)**	Measures the time from switching on the DUT to the availability of the first valid location fix.
5	**Reacquisition time**	Measures how long it takes for the DUT to restore its position information after having lost the GNSS signals for a certain period of time.
6	**Tracking and acquisition sensitivity**	Determines the minimum required signal level that allows the receiver to successfully perform or maintain a position fix.
7	**Functional RAIM test**	Determines the DUT's ability to detect and exclude faulty GNSS signals.

Thank your for your attention