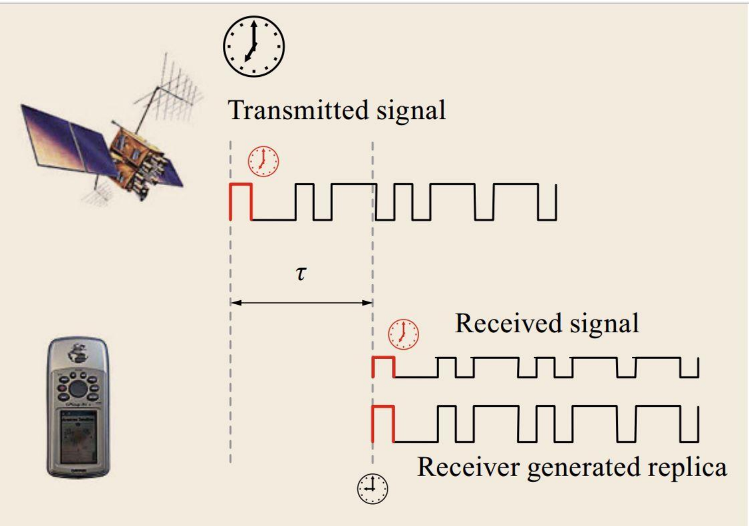


GNSS SIGNALS and POSITIONING TECHNIQUES

Bigyan Banjara

Ashadh 1, 2077

Departure Points

- Why GPS? Why not GNSS? What about RNSS?

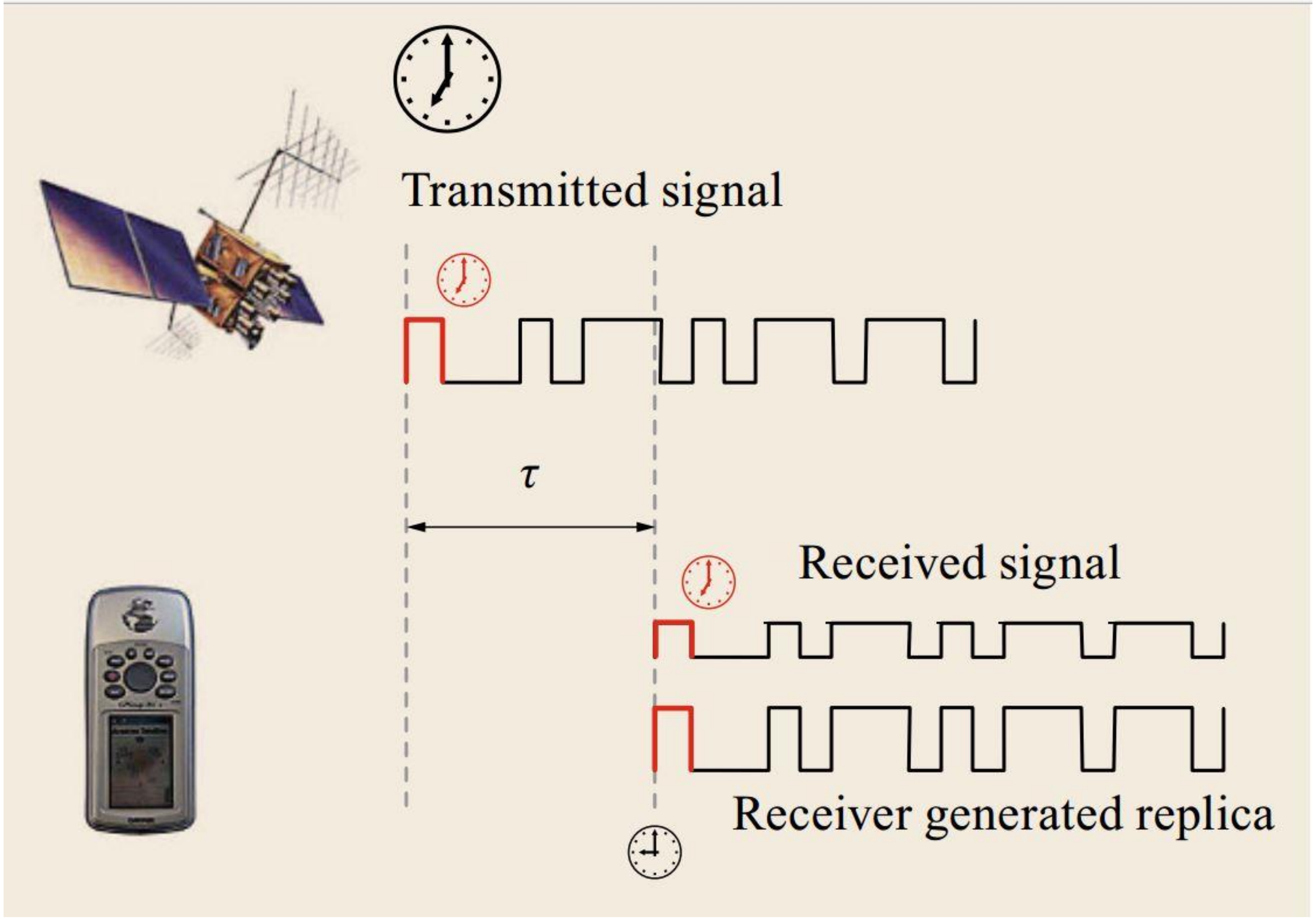
- GPS: Global Positioning System
- GNSS: Global navigation Satellite System
- RNSS: Regional Navigation Satellite System

GNSS and RNSS

System	GPS	GLONASS	BeiDou	Galileo	QZSS	IRNSS/NavIC
Orbit	MEO	MEO	MEO, IGSO, GEO	MEO	IGSO, GEO	IGSO, GEO
Nominal number of satellites	24	24	27, 3, 5	30	3, 1	4, 3
Constellation	6 planes 56° inclination	Walker (24/3/1) 64.8° inclination	Walker (24/3/1) 55° inclination	Walker (24/3/1) 56° inclination	IGSOs with 43° inclination	IGSOs with 29° inclination
Services	SPS, PPS	SPS, PPS	OS, AS, WADS, SMS	OS, CS, PRS	GCS, GAS, PRS, EWS, MCS	SPS, RS
Initial service	Dec 1993	Sep 1993	Dec 2012	2016/2017 (planned)	2018 (planned)	2016 (planned)
Origin	USA	Russia	China	Europe	Japan	India
Coverage	Global	Global	Global	Global	East Asia Oceania region	$-30° < \phi < 50°$ $30° < \lambda < 130°$
Frequency (MHz)	L1 1575.42 L2 1227.60 L5 1176.45	L1 1602.00 L2 1246.00 L3 1202.025	B1 1561.098 B2 1207.14 B3 1268.52	E1 1575.42 E5a 1176.45 E5b 1207.14 E6 1278.75	L1 1575.42 L2 1227.60 L5 1176.45 E6 1278.75	L5 1176.45 S 2492.028

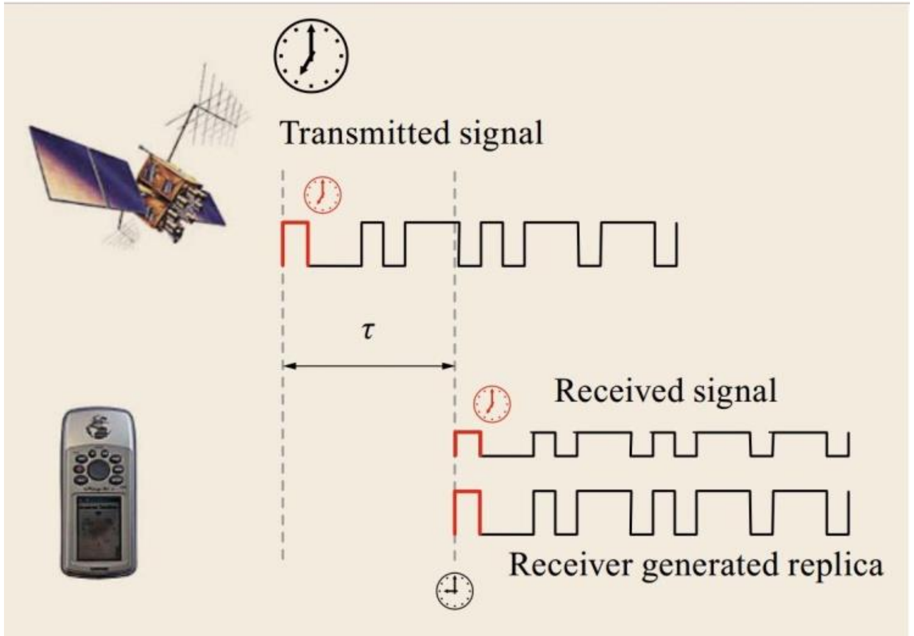
SPS: Standard Positioning Service; PPS: Precise Positioning Service; OS: Open Service; AS: Authorized Service; WADS: Wide Area Differential Service; SMS: Short Message Service; CS: Commercial Service; PRS: Public Regulated Service; GCS: GPS Complementary Service; GAS: GPS Augmentation Service; EWS: Early Warning Service; MCS: Message Communications Service; PS: Precision Service; RS: Restricted Service

GNSS Working principle



Range meaurements

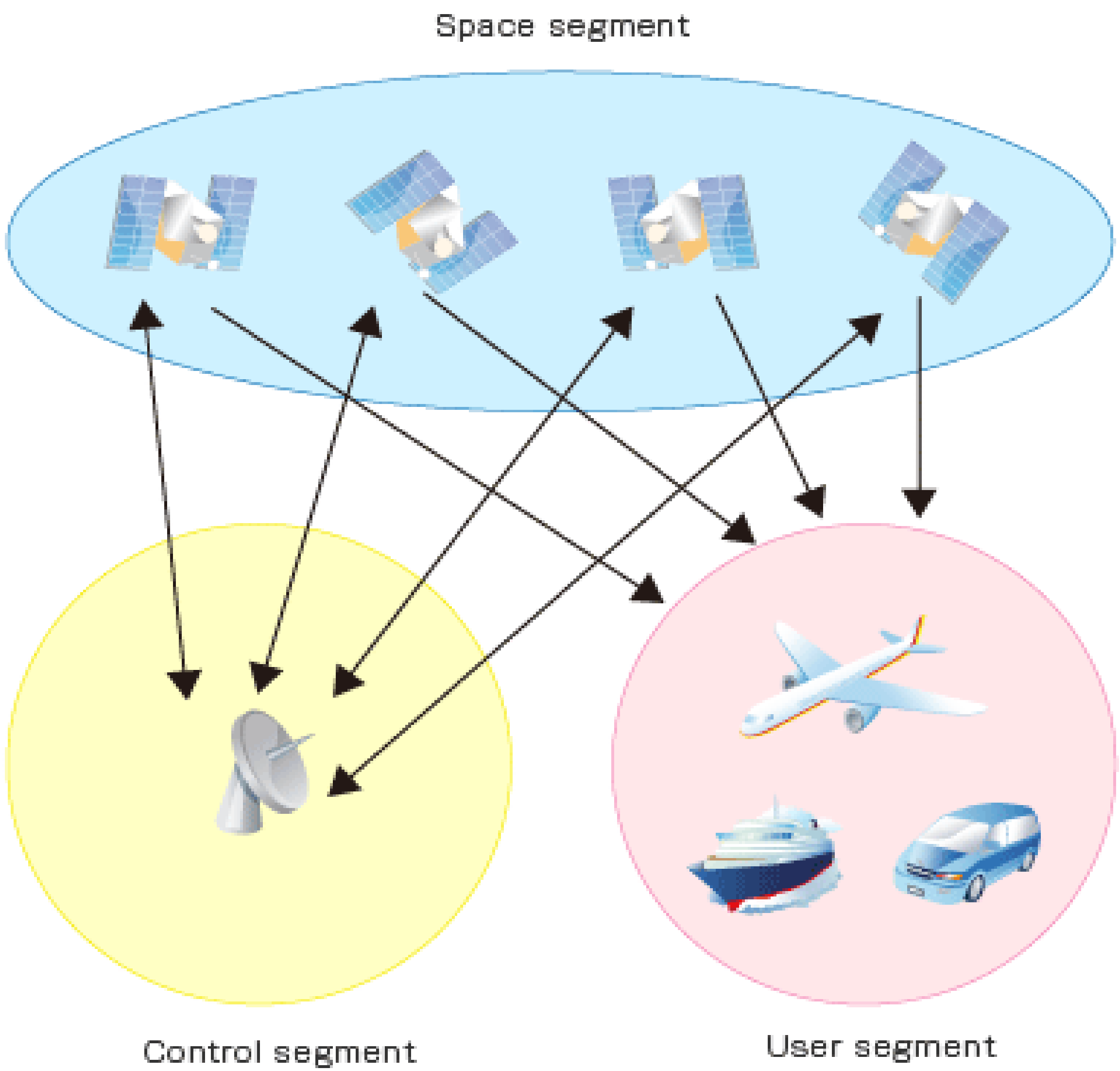
- How is distance computed?



- The distance or range from receiver to satellite are obtained by:

  Range = transit time * speed of light

Components of GNSS

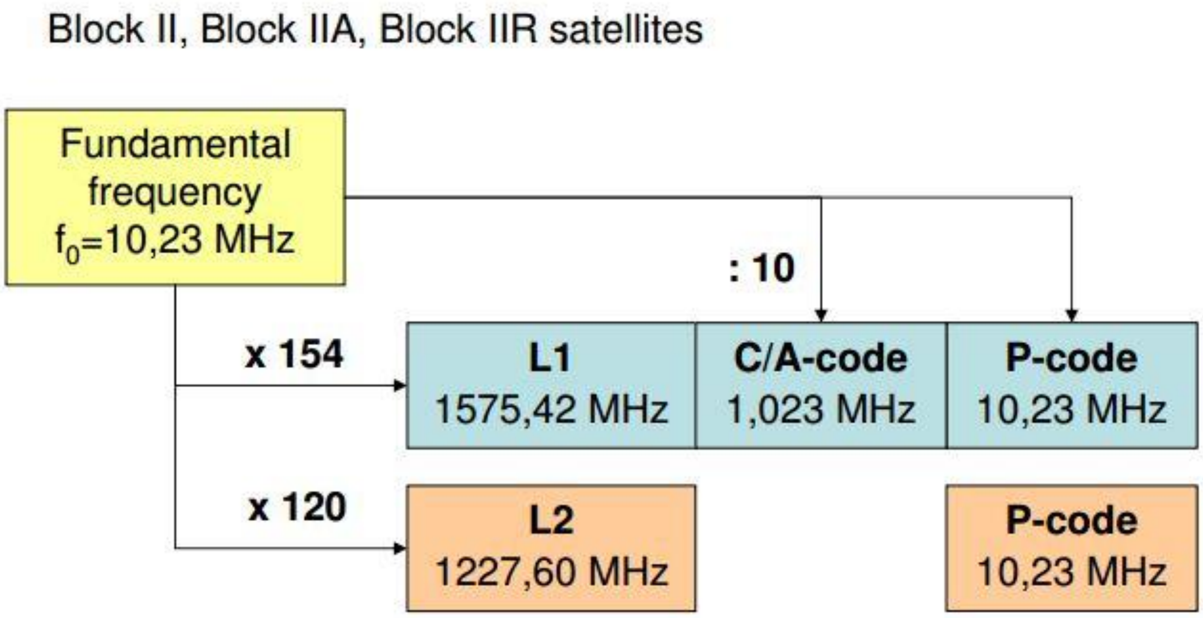


Components of GNSS

- The **space segment** comprises a constellation of satellites orbiting above the Earth's surface that transmit ranging signals on at least two frequencies in the microwave part of the radio spectrum.
- The **control segment** is responsible for maintaining the health of the system by monitoring the broadcast signals and computing and uploading to the satellites required navigation data. It consists of a group of globally (or locally)-dispersed monitoring stations, ground antennas for communicating with the satellites, and a master control station with a backup facility at a different location.
- The **user segment** consists of GNSS receiving equipment both civil and military. This includes receivers on the ground, at sea, in the air, and even in space.

PART I:
GNSS Signals

GPS signals



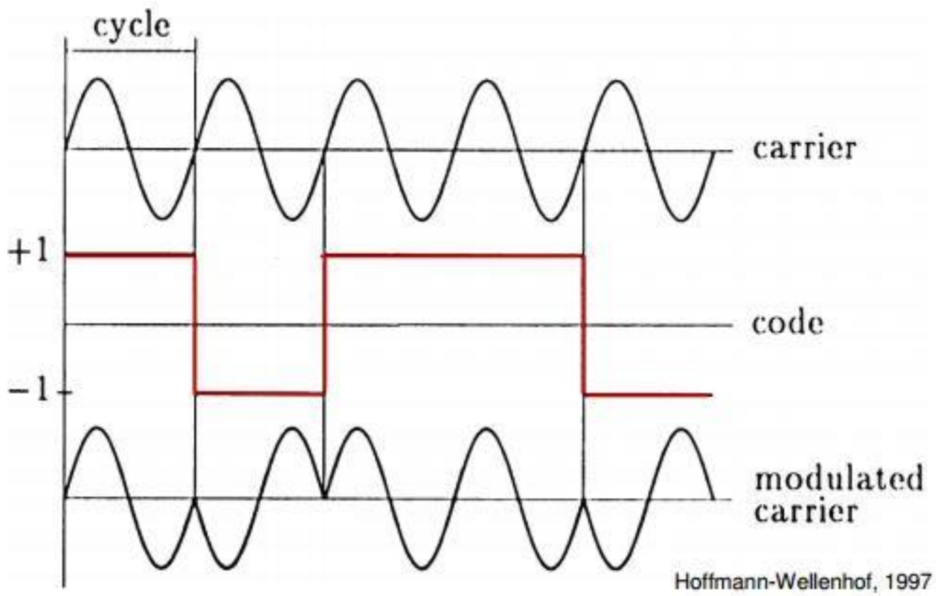
GNSS provide signals on at least two different frequencies for compensation of ionospheric delays in their measurements.

GNSS Signals

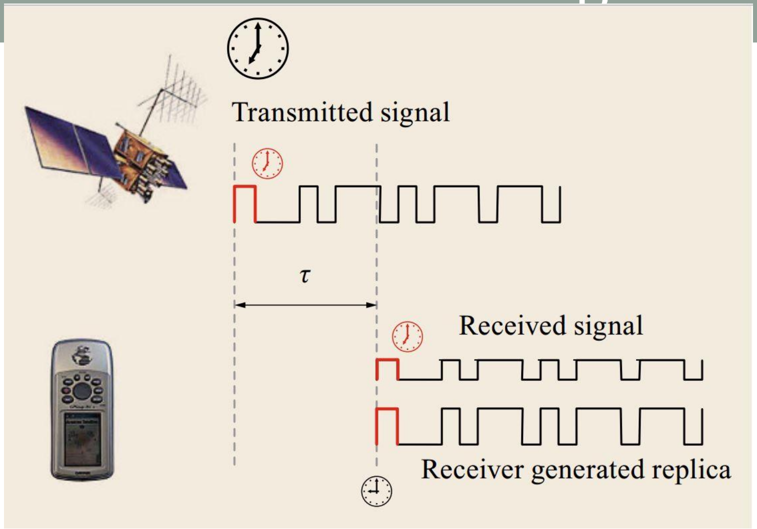
- GNSS signals are electromagnetic waves propagating at the speed of light.
- Signal frequencies in the radio spectrum between about 1.2 and1.6 GHz (a part of the so-called L-band) have been selected for these signals since:
  - these enable measurements of adequate precision,
  - allow for reasonably simple user equipment and
  - do not suffer from attenuation in the atmosphere under common weather conditions.
- At the given frequencies, GNSS signals have a wavelength of about 19–25 cm.

GNSS signals

- The GNSS signals enable three basic types of measurements:
  1. Pseudorange
  2. carrier Phase
  3. Doppler

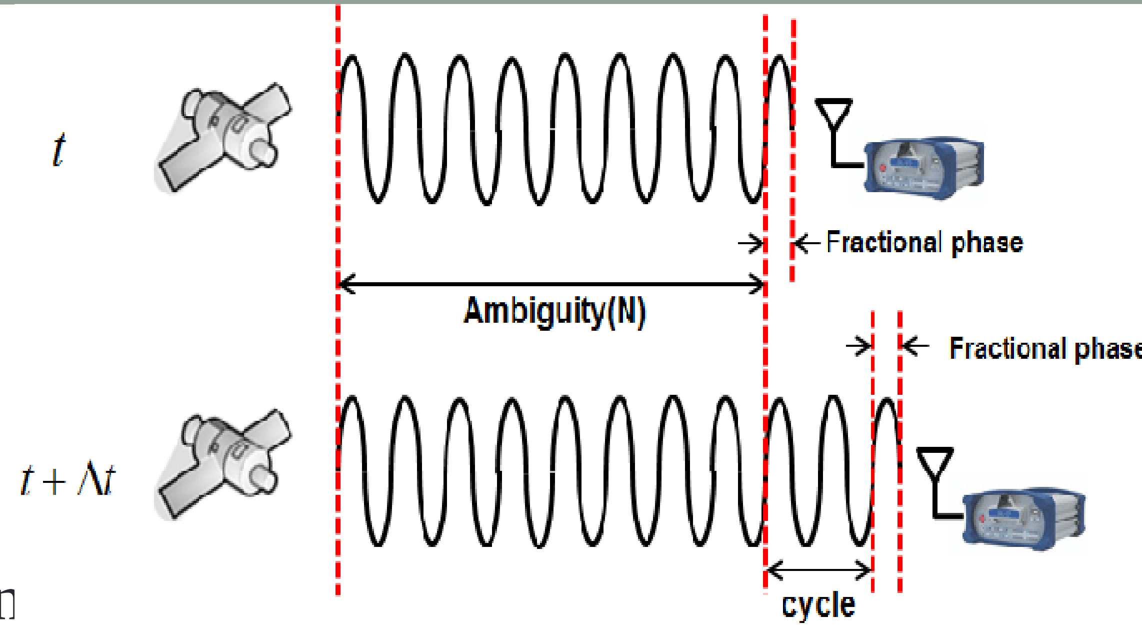


Pseudorange



- A measure of the difference between the receiver clock at signal reception and the satellite clock at signal transmission (scaled by the speed of light).
- Except for the two asynchronous clocks and some other delays, the pseudorange measures the satellite–receiver distance, the precision of which is in the decimetre range.

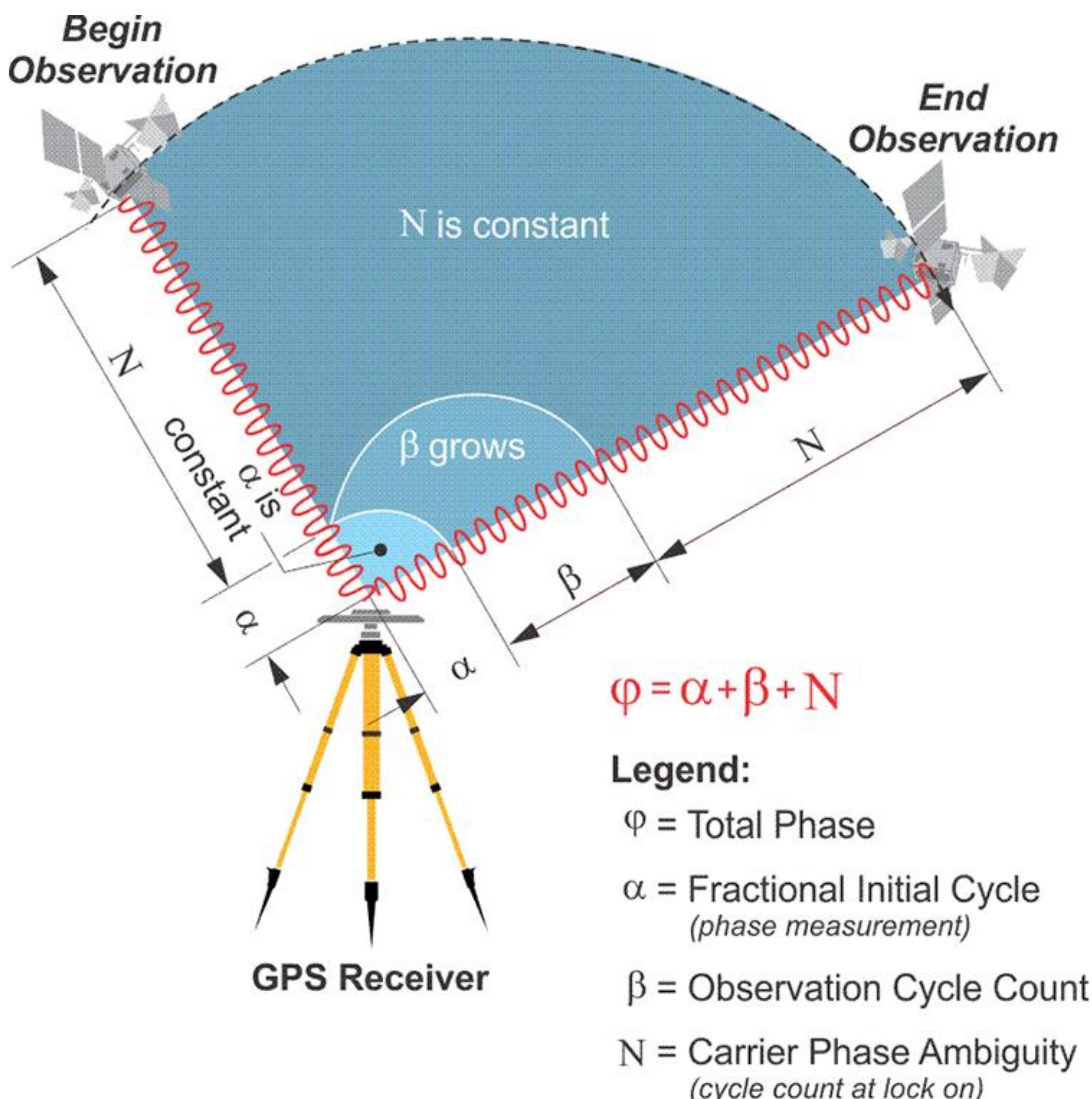
Carrier phase



- A measure of the instan number of zero-crossings obtained after mixing with a reference signal of the nominal frequency.

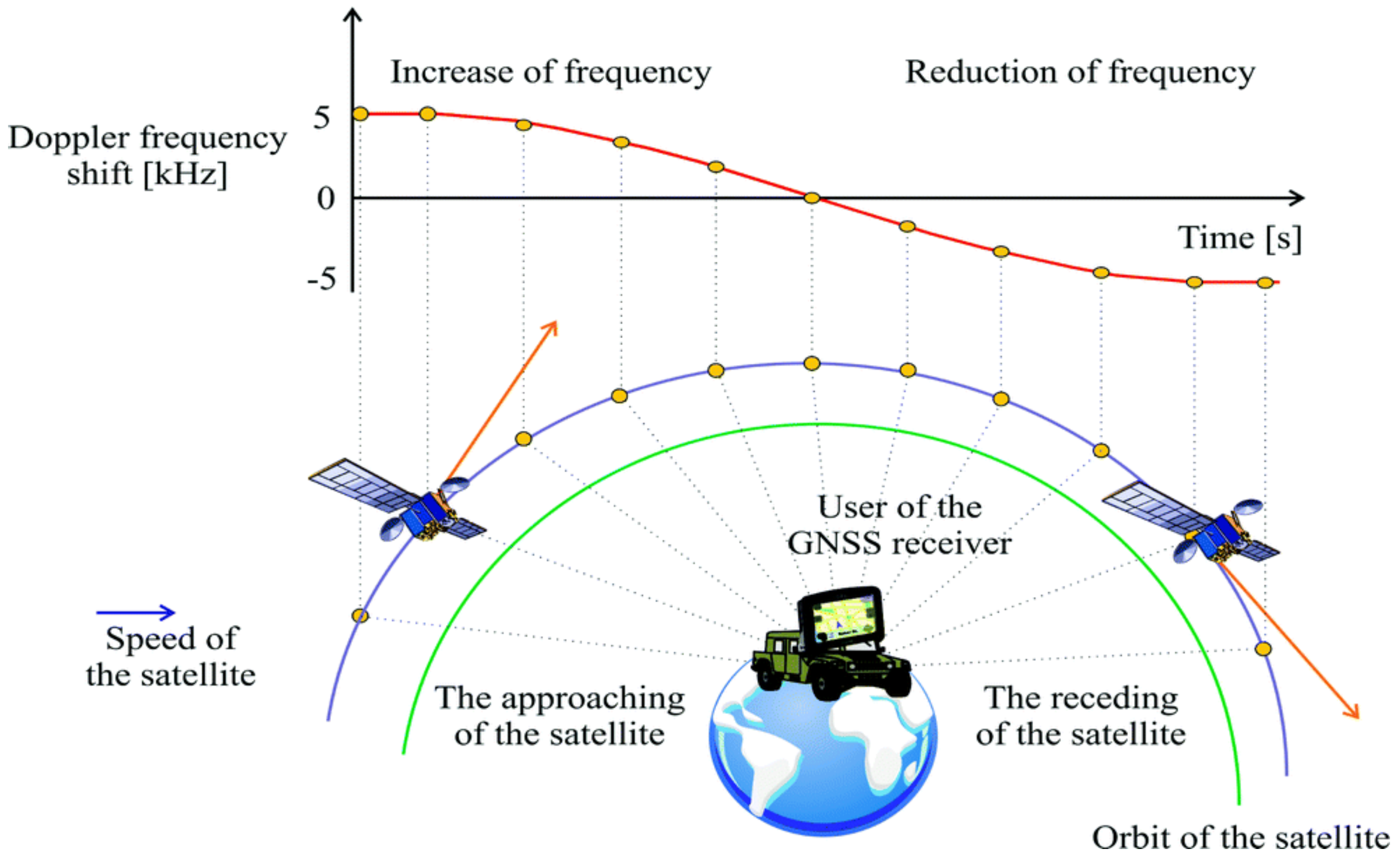
- Changes in carrier phase over time reflect the change in (pseudo)range but are substantially more precise.

- In case of interrupted tracking the accumulated cycle count is lost and the carrier-phase measurements exhibit a cycle slip.



Begin Observation
End Observation
N is constant
β grows
N
constant
α is
α
β
α
N
φ = α + β + N
GPS Receiver
Legend:
φ = Total Phase
α = Fractional Initial Cycle
(phase measurement)
β = Observation Cycle Count
N = Carrier Phase Ambiguity
(cycle count at lock on)

Doppler

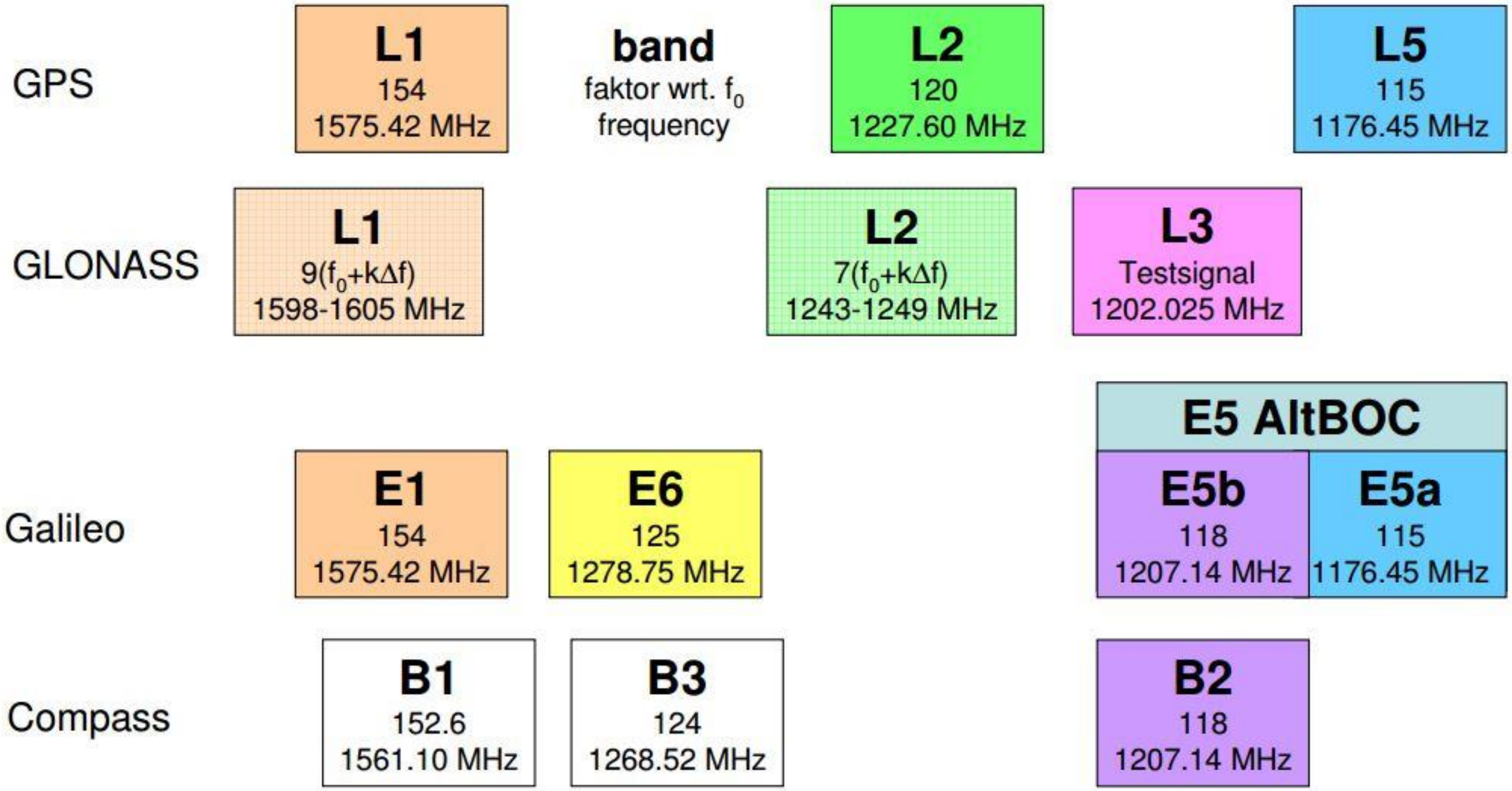


- The change in the received frequency caused by the Doppler effect is a measure of the range-rate or line-of-sight velocity.

GNSS Signal Overview

- The GNSS signals have to be designed to provide the users all necessary information needed for positioning.
- The signals
  - allow the identification of the individual satellites,
  - contain the time tags required for the travel time measurement, and
  - provide all additional information required such as the satellite positions.
  - Because the concepts are very similar for all GNSS, we discuss the signal structure on the GPS as an example.

GNSS signals (all constellations)



GPS signals

- All frequencies and signals broadcast by GPS satellites are derived from a fundamental frequency generated by the on-board oscillator.
- The fundamental frequency is $f_0 = 10.23$ MHz.
- The following two carrier frequencies (sine/cosine waves) are broadcast by GPS satellites:
  - L1: $f_1 = 154.f_0 = 1575.43$ MHz $\lambda = 19$ cm
  - L2: $f_2 = 120.f_0 = 1227.60$ MHz $\lambda = 24$ cm
- The modernized GPS satellites of Block IIF (since 2010) and Block III (2017) provide signals on a third carrier frequency:
  - L5: $f_2 = 115.f_0 = 1176.45$ MHz $\lambda = 26$ cm
  - The microwave radiation is **right-handed circularly polarized** in order to suppress reflected signals.

GPS signals

Code	C/A-Code	P-Code	Nav
Chiping frequency	1.023 MHz	10.23 MHz	50 Hz
Chiping rate	1.023 Mbps	10.23 Mbps	50 bps
Chip length	1 µs	0.1 µs	20 ms
	293 m	29.3 m	(5.9 km)
Repetition rate	1 ms	1 week	30 s
Number of chips	1000	$6 \cdot 10^{12}$	1500

- The chip length of the codes is related with the *code measurement precision*. Typically a receiver is able to measure with a precision of 1/100 of the chip length.

GPS signals

- **C/A-Code: Advantages/Disadvantages:**
  - **Freely available** (Clear Access), civil signal.
  - **Less precise** than the P-Code (Coarse Acquisition), chip length 300 m, measurement accuracy about 3 m.
  - Used for the **identification of the satellites** (PRN number)
  - Only modulated on the **L1 carrier**.
  - **Rapid acquisition**: The repetition rate is only 1 ms.

GPS signals

- **P-Code: Advantages/Disadvantages**
  - Encrypted (Protected), only accessible to authorized users. Encryption key is secret. Military signal.
  - Higher precision (Precise), chip length 30 m, measurement accuracy about 30 cm.
  - Modulated on both carriers.
  - Acquisition more complex due to long code sequence (1 week).

PART II:
Positioning Techniques

Positioning Techniques

- Single Point Positioning
- Relative or Differential Positioning
- Code phase measurements
- Carrier phase measurements
- Static and kinematic measurements
- RTK Methods
- Post-procesing of GNSS observations

Single Point positioning

- Also known as **Absolute Positioning.**
- Position of a station is computed based on the observation at the antenna of the same receiver.
- For precise positioning, the user should apply proper corrections for all possible sources of errors, such as
  - Satellite and receiver clock offsets
  - Troposphere and ionospheric delays
  - Multipath
  - Earth tides,
  - Integer ambiguities (for carrier phase measurements)
  - Hardware bias, etc.
- For example: Continouusly Operating Reference Station

Relative/differential positioning

- Positioning based on the differencing of measurements from two or more receivers and/or satellites.
- Error sources are either reduced or eliminated based on the type of differencing used.
- **Types:**
  - SINGLE DIFFRENCING
    - Satellite-to-satellite differencing (eliminates receiver dependent errors)
    - Receiver-to-receiver differencing (eliminates satellite dependent errors)
  - DOUBLE DIFFERENCING
    - Eliminates both satellite and receiver dependent errors
    - Reduces distance dependent errors such as troposphere and ionosphere delays
  - TRIPLE DIFFERENCING (eliminates integer ambiguities)

Code phase positioning

- Use of phase shifts (0 and 1) of PRN codes for transit time determination.
- The range between the satellites and the receiver is then computed by:

RANGE = transit time x speed of light

Carrier phase positioning

- Use of phase shifts of carrier phase measurements for more accurate reslts.
- The accuracy of up to few milimeters can be achieved using carrier phase measurements.
- The overall accuracy of carrier phase measurements depends on the accuracy with which the integer ambiguity is estimeted by the GNSS processing software.
- Integer ambiguity is the complete number of cycles completed by the GNSS signals, between the satellite and the receiver.

Static measurements

- Measurements on the receivers that are at rest.
- Positioning mode can be either be absolute or relative.
- If the positioning mode is relative, both the reference and the rover receivers are at rest.
- Static positioning mode generaly yields in higher positioning accuracy.

Kinematic measurements

- Kinematic positioning mode refers to the motion of either the rover alone or the both (reference and rover)
- Accuracy is generally lower than that of the static positioning mode.
- The results from the kinematic positioning can be obtained:
  - at the real time in the field (called **True Real Time Kinematics (RTK)** or simply **RTK**) or
  - after post processing in office (**Post-processed RTK**)

Precise Point Positioning

- Precise point positioning (PPP) is an advanced version of the single-point positioning (SPP) technique.
- PPP uses carrier-phase measurements as the primary observable with pseudorange measurements playing a secondary role.
- All the effects causing errors up-to few centimetre-level, must be considered. For example:
  - Satellite orbits and clock offsets,
  - Troposphere and ionosphe delays
  - Antenna offsets
  - Integer ambiguities
  - Multipath

RTK techniques

- In real-time kinematic (RTK) positioning, a GNSS reference station transmits carrier-phase and pseudorange data over a radio link to a roving station.
- The reference station transmits pseudorange and carrier-phase measurements and ancillary data.

Post processing of GNSS signals

- Post-processing of GNSS signals are more accurate than the RTK because of the following reasons:
  - Precise orbits and clock information helps to reduce the errors due to satellite position and satellite clock offsets.
  - Precse models on troposphere and ionospheric delays can be used for mitigating the corresponding delays.
  - Precise antenna calibration models helps to reduce the antenna-specific errors.

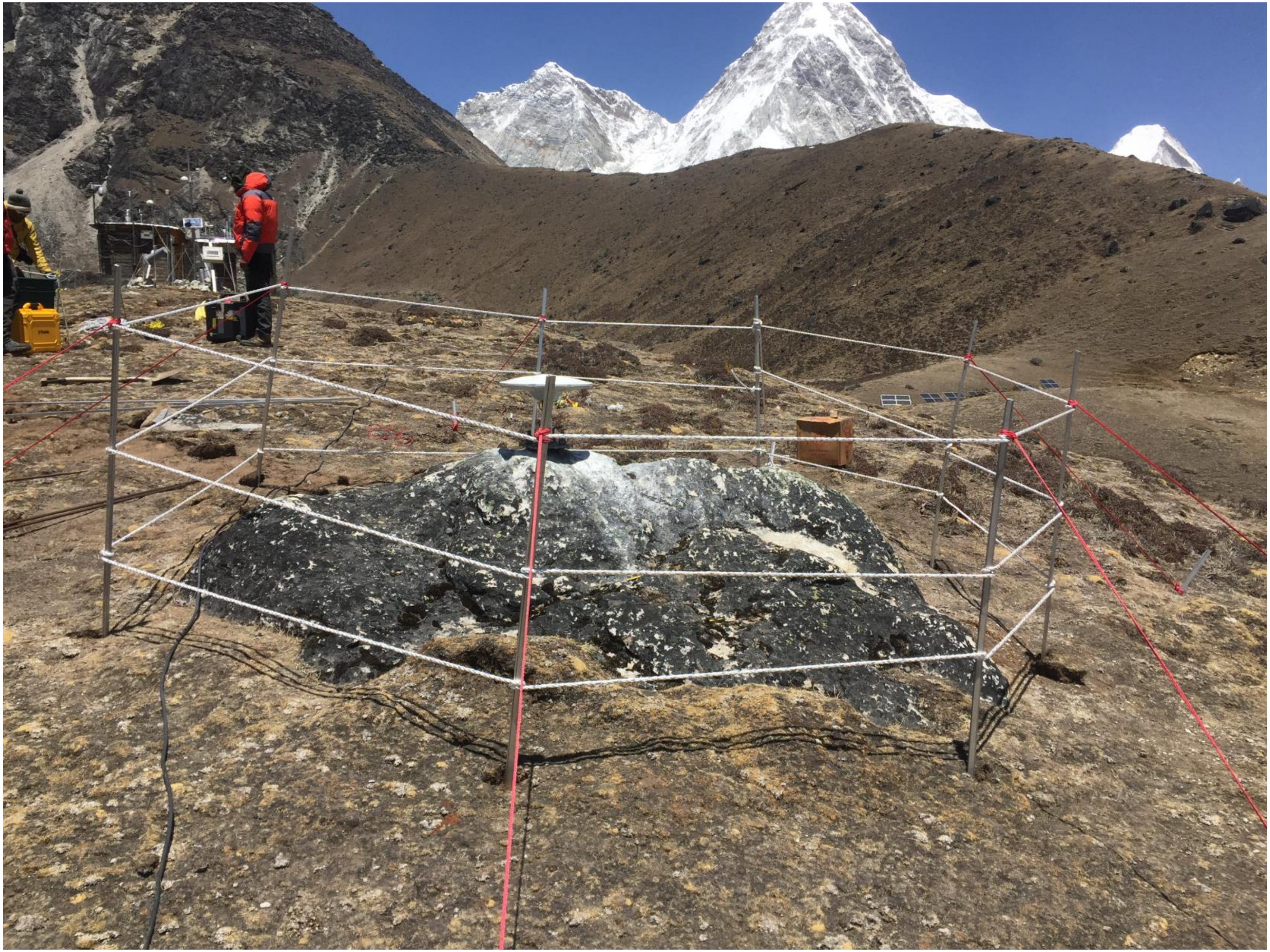
PART III:
GNSS Accessories, Monuments, Available CORS in Nepal

GNSS Observation at Laure Danda, Khotang

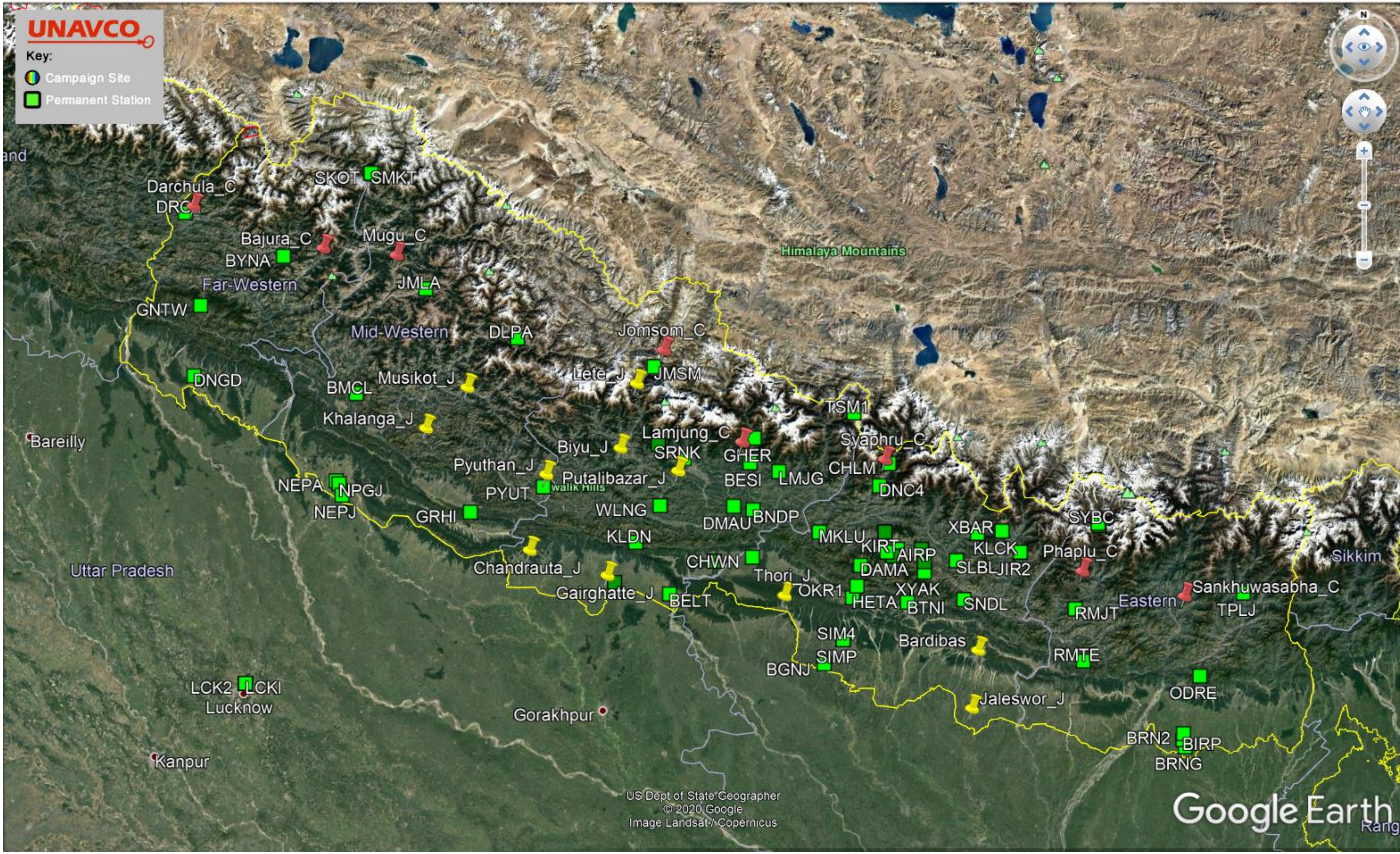
Monument Types

Monument Design@Mahesh Thapa

Temporary CORS established for Sagarmatha Height Measurement



CORS established by DMG in co-opertaion with several International agencies

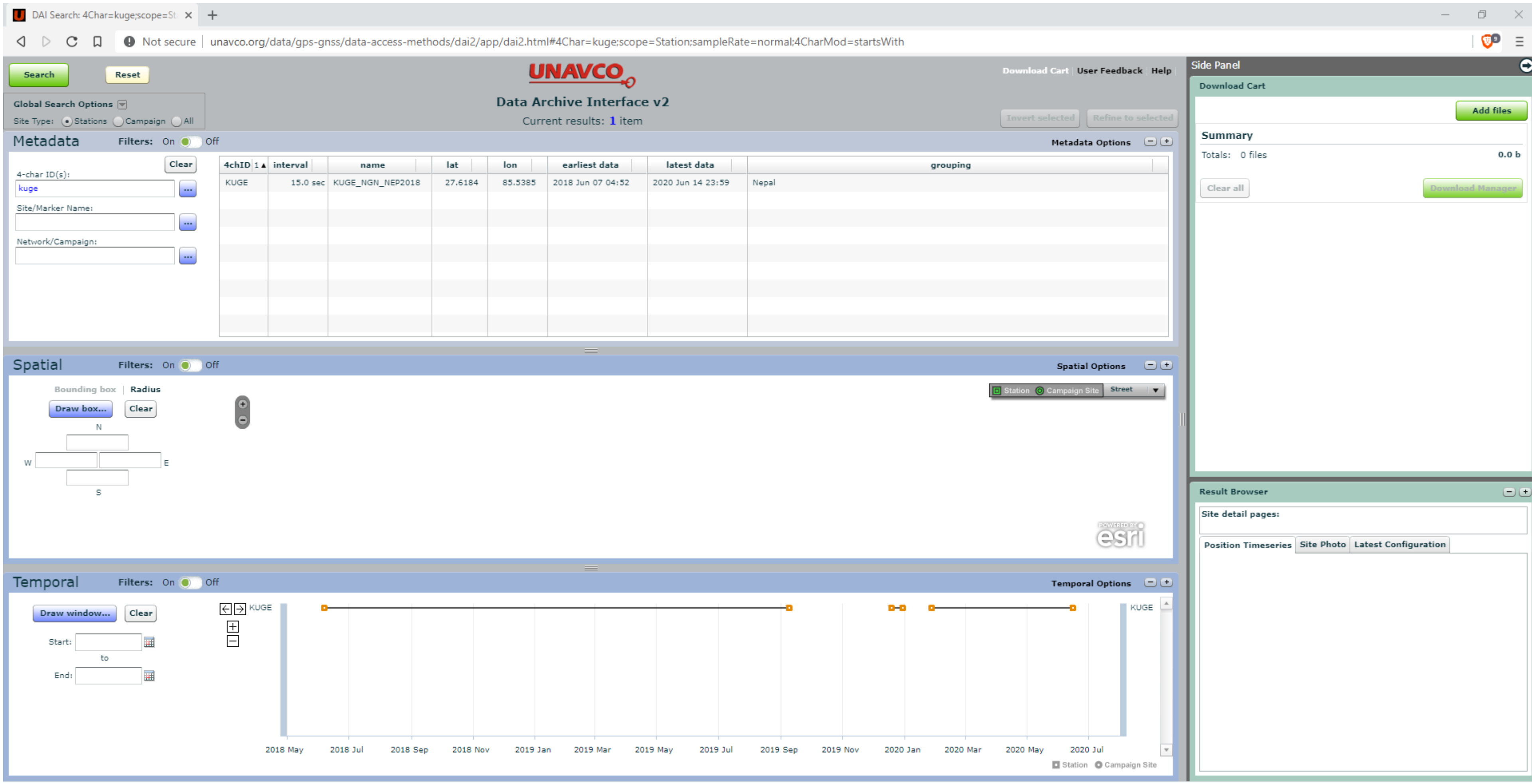


Summary of CORS as of Feb 26, 2020

	A	B	C	D	E	F	G	H	I	J	K	L
1	**Status of CORS in Nepal as of February 26, 2020**											
2												
3	**4chID**	**interval**	**name**	**latest rx model**	**latest ant model**	**style**	**status**	**lat**	**lon**	**earliest data**	**latest data**	**grouping**
4	BESI	15.0 sec	Besisahar	TRIMBLE NETR9	TRM41249.00	building roof	Active	28.2286	84.3797	2008 Jun 28 11:56	2019 Jul 05 21:20	Nepal
5	BRN2	15.0 sec	Biratnagar 2	TRIMBLE NETR9	ASH701945B_M	shallow-drilled braced	Active	26.5197	87.2722	2009 May 21 06:07	2020 Feb 25 23:59	Met Sites, NEGAR Nepal
6	CHLM	15.0 sec	Chilime	TRIMBLE NETR8	ASH701945E_M	shallow-drilled braced	Active	28.2072	85.3141	2004 Mar 31 08:58	2020 Feb 25 23:59	NEGAR Nepal
7	CHWN	15.0 sec	Chitwan	TRIMBLE NETR8	TRM57971.00	shallow-drilled braced	Active	27.6682	84.3853	2011 Mar 28 08:34	2019 Apr 08 23:59	NEGAR Nepal
8	DLPA	15.0 sec	Dolpa	TRIMBLE NETR9	TRM29659.00	shallow-drilled braced	Active	28.9837	82.8179	2007 May 10 00:00	2019 Apr 12 23:59	NEGAR Nepal
9	DNGD	15.0 sec	Dhangadi	TRIMBLE NETR8	TRM57971.00	shallow-drilled braced	Active	28.7544	80.5818	2008 May 06 15:04	2019 Aug 17 23:59	NEGAR Nepal
10	DNSG	15.0 sec	Dansing	TRIMBLE NETR9	TRM57971.00	rock-pin	Active	28.3451	83.7635	2012 Apr 29 10:30	2020 Feb 24 00:24	NEGAR Nepal
11	DRCL	15.0 sec	Darchula	TRIMBLE NETR9	TRM57971.00	shallow-drilled braced	Active	29.7338	80.5009	2008 Mar 13 11:01	2019 Aug 20 04:20	NEGAR Nepal
12	GRHI	15.0 sec	Ghorahi	TRIMBLE NETR8	TRM29659.00	shallow-drilled braced	Active	27.9508	82.4912	2007 May 07 00:00	2018 Apr 27 11:28	NEGAR Nepal
13	HETA	15.0 sec	Hetuada GoN Fish Farm	TRIMBLE NETR9	TRM57971.00	shallow-drilled braced	Active	27.4149	85.0516	2015 Jun 11 05:44	2020 Feb 04 23:59	Nepal
14	JIR2	15.0 sec	JIR2	TRIMBLE NETR8	TRM57971.00	rock-pin	Active	27.6571	86.187	2015 May 25 02:39	2020 Feb 25 23:59	Nepal
15	JMLA	15.0 sec	Jumla	TRIMBLE NETR9	TRM29659.00	shallow-drilled braced	Active	29.2778	82.1926	2007 May 16 00:00	2018 Sep 24 23:59	NEGAR Nepal
16	JMSM	15.0 sec	Jomsom	TRIMBLE NETR9	ASH701945B_M	shallow-drilled braced	Active	28.8053	83.7433	2004 May 02 11:02	2020 Feb 25 23:59	NEGAR Nepal
17	KKN4	15.0 sec	Kakani 4	TRIMBLE NETR9	TRM57971.00	shallow-drilled braced	Active	27.8007	85.2788	2004 Mar 22 10:00	2019 Dec 15 09:51	NEGAR Nepal
18	KUGE	15.0 sec	KUGE_NGN_NEP2018	TRIMBLE NETR9	TRM115000.00	deep-driven rod braced	Active	27.6184	85.5385	2018 Jun 07 04:52	2020 Feb 25 23:59	Nepal
19	LMJG	15.0 sec	Lamjung	TRIMBLE NETR9	TRM57971.00	shallow-drilled braced	Active	28.1741	84.5734	2011 Apr 20 08:02	2020 Feb 24 23:59	NEGAR Nepal
20	NAST	15.0 sec	NAST_SciTec_2013	TRIMBLE NETR9	TRM57971.00	shallow-drilled braced	Active	27.6567	85.3277	2014 Jan 18 00:00	2019 Dec 11 23:59	NEGAR Nepal
21	NPGJ	15.0 sec	Nepalganj	TRIMBLE NETR9	TRM29659.00	shallow-drilled braced	Active	28.1172	81.5953	2007 May 19 04:47	2020 Feb 24 23:59	NEGAR Nepal
22	ODRE	15.0 sec	Odare	TRIMBLE NETR9	TRM57971.00	shallow-drilled braced	Active	26.8661	87.3921	2007 Jan 01 00:00	2019 Dec 23 23:59	NEGAR Nepal
23	RMJT	15.0 sec	Rumjartar	TRIMBLE NETR9	TRM29659.00	shallow-drilled braced	Active	27.3051	86.55	2009 Nov 05 09:34	2020 Feb 25 23:59	NEGAR Nepal
24	SNDL	15.0 sec	Sindhuli	TRIMBLE NETR8	TRM57971.00	shallow-drilled braced	Active	27.3848	85.7989	2011 Apr 05 12:09	2020 Feb 25 23:59	NEGAR Nepal
25	SYBC	15.0 sec	Syangboche	TRIMBLE NETR9	TRM29659.00	shallow-drilled braced	Active	27.8142	86.7125	2008 Oct 04 04:34	2020 Feb 25 23:59	NEGAR Nepal
26												
27	AIRP	15.0 sec	Tribhuvan International Airport	TRIMBLE NETR9	TRM57971.00	permanent station unspecified	Retired	27.6972	85.3579	2015 May 11 06:04	2015 Jul 24 23:59	Nepal
28	BELT	15.0 sec	Belatari	TRIMBLE NETRS	TRM41249.00	building roof	Retired	27.457	83.826	2008 Jul 06 06:04	2017 Feb 03 23:59	Nepal
29	BGNJ	15.0 sec	Birgunj	TRIMBLE R5	TRM57971.00	shallow-drilled braced	Retired	27.0237	84.8527	2015 Jun 25 13:52	2016 Sep 09 10:25	Nepal
30	BIRP	30.0 sec	Biratnagar	TRIMBLE 4000SSI	TRM22020.00+GP	shallow foundation pillar	Retired	26.4838	87.267	1996 Dec 09 11:18	2001 Oct 24 09:09	Nepal
31	BMCL	15.0 sec	Bhimchula	TRIMBLE NETRS	TRM41249.00	shallow-drilled braced	Retired	28.6558	81.7144	2007 Mar 18 08:58	2016 Jun 26 23:59	NEGAR Nepal
32	BNDP	15.0 sec	Bandipur_NPL2012	TRIMBLE NETR8	TRM57971.00	rock-pin	Retired	27.9495	84.3951	2015 May 02 10:25	2016 Jul 16 23:59	NEGAR Nepal
33	BRNG	30.0 sec	Biratnagar	ASHTECH UZ-12	ASH701945B_M	shallow-drilled braced	Retired	26.4387	87.2812	2004 Mar 14 05:02	2009 Apr 11 07:23	NEGAR Nepal
34	BRWA	15.0 sec	Bhairahaba	TRIMBLE R5	TRM57971.00	shallow-drilled braced	Retired	27.5291	83.4577	2015 Jun 27 13:57	2017 Jan 10 08:19	Nepal
35	BTNI	15.0 sec	BTNI	TRIMBLE NETR9	TRM57971.00	rock-pin	Retired	27.3797	85.4194	2015 Jun 12 11:16	2016 Oct 30 02:03	Nepal
36	BYNA	15.0 sec	Bayana	TRIMBLE NETRS	TRM29659.00	shallow-drilled braced	Retired	29.4742	81.2007	2008 May 03 09:40	2012 Jun 28 23:59	NEGAR Nepal
37	DAMA	15.0 sec	DAMA_DASE_NP1997	TRIMBLE NETRS	ASH700936D_M	shallow foundation pillar	Retired	27.6082	85.1076	2015 Jun 25 00:00	2016 May 10 23:59	Nepal

Q: Where Can I get the CORS Data?

A: https://www.unavco.org/data/gps-gnss/data-access-methods/dai2/app/dai2.html



LOBU1410.19O

```
     3.03           OBSERVATION DATA    Mixed(MIXED)        RINEX VERSION / TYPE
cnvtToRINEX 3.11.0  convertToRINEX OPR  25-Nov-19 07:18 UTC PGM / RUN BY / DATE
------------------------------------------------------------ COMMENT
LOBU                                                        MARKER NAME
                                                            MARKER NUMBER
GEODETIC                                                    MARKER TYPE
GNSS Observer       Trimble                                 OBSERVER / AGENCY
5739R03603          TRIMBLE R9S                 5.40        REC # / TYPE / VERS
                    TRM115000.10    NONE                    ANT # / TYPE
   313487.9988  5633659.1932  2974701.2506                  APPROX POSITION XYZ
        0.1500        0.0000        0.0000                  ANTENNA: DELTA H/E/N
G    8 C1C C2W C2X C5X L1C L2W L2X L5X                      SYS / # / OBS TYPES
I    2 C5A L5A                                              SYS / # / OBS TYPES
J   10 C1C C1X C1Z C2X C5X L1C L1X L1Z L2X L5X              SYS / # / OBS TYPES
E    8 C1X C5X C7X C8X L1X L5X L7X L8X                      SYS / # / OBS TYPES
R   10 C1C C1P C2C C2P C3X L1C L1P L2C L2P L3X              SYS / # / OBS TYPES
C    4 C2I C7I L2I L7I                                      SYS / # / OBS TYPES
     1.000                                                  INTERVAL
  2019     5    21     0     0    0.0000000     GPS         TIME OF FIRST OBS
  2019     5    21    23    59   59.0000000     GPS         TIME OF LAST OBS
     0                                                      RCV CLOCK OFFS APPL
 24 R01  1 R02 -4 R03  5 R04  6 R05  1 R06 -4 R07  5 R08  6 GLONASS SLOT / FRQ #
    R09 -2 R10 -7 R11  0 R12 -1 R13 -2 R14 -7 R15  0 R16 -1 GLONASS SLOT / FRQ #
    R17  4 R18 -3 R19  3 R20  2 R21  4 R22 -3 R23  3 R24  2 GLONASS SLOT / FRQ #
G L2X -0.25000                                              SYS / PHASE SHIFT
J L2X -0.25000                                              SYS / PHASE SHIFT
R L1P  0.25000                                              SYS / PHASE SHIFT
R L2C -0.25000                                              SYS / PHASE SHIFT
R L2P  0.00000                                              SYS / PHASE SHIFT
    18                                                      LEAP SECONDS
   116                                                      # OF SATELLITES
   C01 83584 83583 83583 83582                              PRN / # OF OBS
   C02 83585 83585 83585 83585                              PRN / # OF OBS
   C03 83615 83615 83615 83615                              PRN / # OF OBS
   C05 83615 83615 83615 83615                              PRN / # OF OBS
   C06 62435 62435 62435 62435                              PRN / # OF OBS
   C07 60257 60257 60257 60257                              PRN / # OF OBS
   C08 61021 61011 61021 61010                              PRN / # OF OBS
   C09 67206 67195 67195 67191                              PRN / # OF OBS
   C10 70161 70144 70154 70144                              PRN / # OF OBS
   C11 22376 22354 22359 22354                              PRN / # OF OBS
   C12 29607 29606 29606 29606                              PRN / # OF OBS
   C13 68332 68327 68327 68327                              PRN / # OF OBS
   C14 19798 19798 19798 19798                              PRN / # OF OBS
   C16 63629 63627 63627 63623                              PRN / # OF OBS
   C19 12514     0 12514     0                              PRN / # OF OBS
   C20 13197     0 13197     0                              PRN / # OF OBS
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References

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Thank You!