CHALMERS – Space, Earth and Environment

RRY100 – Satellite Communications – 2024 – LAB-4

MEO satellite tracking

1 Introduction

Satellite communication makes use of satellites in various orbits. Besides the classical Geostationary Earth Orbit (GEO), which is often used e.g. for TV-broadcasting, several satellite constellations make use of Medium Earth Orbits (MEO). While GEO satellites appear to be stable w.r.t. to a ground station, do MEO satellites ”move over the sky”. This means that, when using directional antennas, these antennas have to follow the satellite path over the sky by active tracking. On the other hand, omnidirectional antennas will be able to see several MEO satellites simultaneously.

The purpose of this lab exercise is to receive signals of MEO satellites both with directional and omnidirectional antennas. The signal spectra shall be studied and the speed of the satellites shall be determined. To do so, we will observe a couple of GNSS satellites for this lab exercise, and track them with the 25 m radio telescope at the Onsala Space Observatory as well with usual GNSS receiving equipment.

Expected learning outcome:

- Receive signals of GNSS satellites using an omnidirectionbal antenna.
- Track several GNSS satellites with a highly directive antenna.
- Determine empirically the speed of GNSS satellites.
- Understand different GNSS codes used and measure their occupied bandwidth.
- Report your results and main lessons learned in the combined ”lab report”.

2 The laborative exercise

1. Empirical determination of satellite speed.

   (a) Set up a usual geodetic GNSS receiving equipment and start observations.

   (b) Read elevation and azimuth for a GNSS satellite from the display of the GNSS receiver.

   (c) Use the python-app `"satlive.py"` on the FS-computer `"fold"` in the observatory control room to steer the 25 m telescope to observe the GNSS satellite.

   (d) Monitor the signal power with a spectrum analyzer.

(e) Watch how a satellite passes through the main-lobe of the 25 m radio telescope and determine the speed of the satellite. Compare this empirically determined speed to the speed calculated from orbital mechanics.

2. Investigation of GNSS signal spectrum.

   (a) Track a GPS satellite with the 25 m telescope.
   (b) Monitor the signal spectrum on L1 and L2 with a spectrum analysator.
   (c) Measure the width of the C/A and P-codes.
   (d) Repeat the above steps for a number of other GPS satellites.

   (e) Do the above steps for a at least one GLONASS satellite.

   (f) Do the above steps for a at least one Galileo satellite.

   (g) Is it possible to do so for a BeiDou satellite?

Table 1: Your results.

	nr.	speed (km/s)
GPS satellite		
GPS satellite		
GPS satellite		
GPS satellite		
GPS satellite		

GNSS satellite name	frequency	width (MHz)
	L1	
	L2	
	L1	
	L2	
	L1	
	L2	
	L1	
	L2	
	L1	
	L2	
	L1	
	L2	
	L1	
	L2	
	L1	
	L2	
	L1	
	L2	
	L1	
	L2	

3 Feed back

Comments and suggestions for improving this lab exercise are much appreciated and can be sent to
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Appendix

Table 2: Some parameters of MEO GNSS systems.

	GPS	GLONASS	Galileo	BeiDou
orbital radius (km)	26560	25510	23916	27878
inclination (°)	55	64.8	56	55
nominal eccentricity	0	0	0.002	0
number of orbital planes	6	3	3	3
number of active satellites	> 24	> 24	> 24	> 24
carrier frequency (MHz)	L1: 1575.42 L2: 1227.60 L5: 1176.45	G1: 1602 + n·0.5625 G2: 1246 + n·0.4375	E1: 1575.42 E6: 1278.75 E5b: 1207.14 E5a: 1176.45	B1: 1575.42 B2: 1207.14 B2a: 1176.45 B3: 1268.52
multiple access technique	CDMA	FDMA	CDMA	CDMA

Some useful information:

Kepler's third law:

$$T^2 = \frac{(4 \cdot \pi^2 \cdot a)}{\mu} \tag{1}$$

Kepler's constant:

$$\mu = 3.986004418 \cdot 10^5 \,\mathrm{km}^3/\mathrm{s}^2 \tag{2}$$

Velocity of a satellite in a circular orbit:

$$v = \sqrt{\frac{\mu}{r}} \tag{3}$$

Full-width half-power beam width of a reflector antenna:

$$\theta_{3\ \mathrm{dB}} = 70^{\circ} \cdot \frac{\lambda}{D} \tag{4}$$

An online GNSS planning softare providing many interesting plots:
`https://www.gnssplanning.com`

The approximate latitude, longitude and ellipsoidal height of the Onsala Space Observatory:

Latitude: 57° 23' N   Longitude: 11° 55' E   Height: 40 m