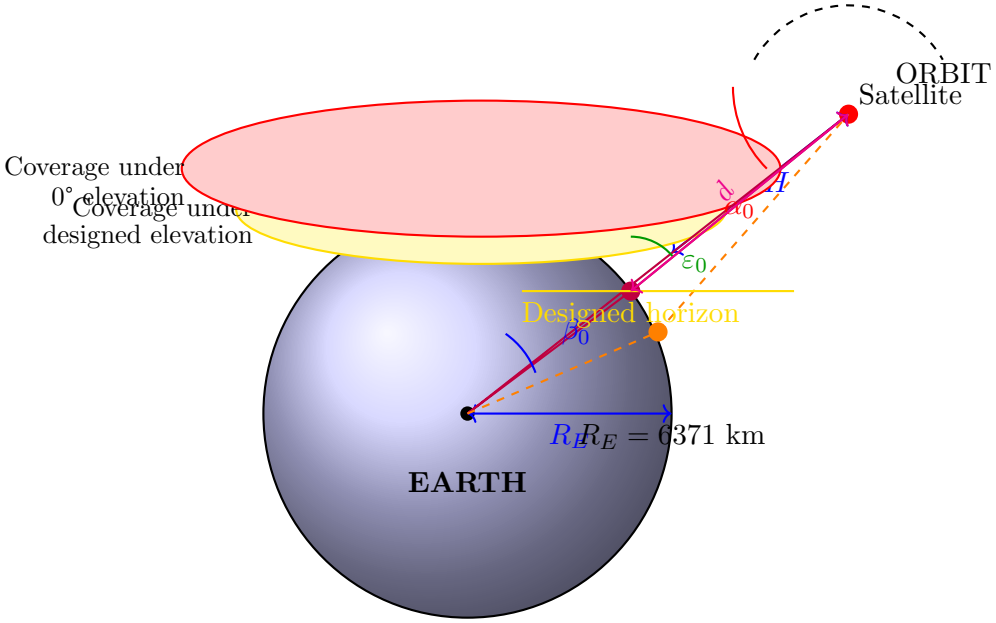
Chapter 5: LEO Coverage

Visual Guide with Diagrams

SPCE 5400 - Ground Station Design

Figure 5.2: LEO Coverage Area Geometry

This is the most critical diagram showing the geometric relationships for coverage calculations.

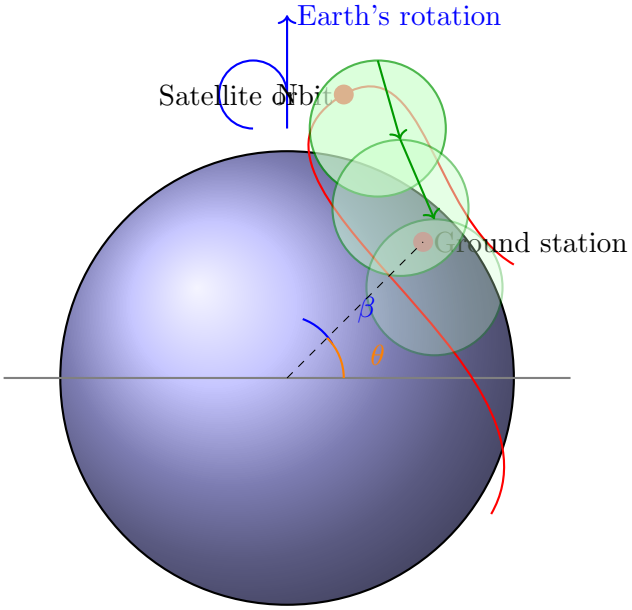


Key Relationships:

- $\varepsilon_0 + \alpha_0 + \beta_0 = 90$
- $\sin \alpha_0 = \frac{R_E}{R_E + H} \cos \varepsilon_0$
- $C[\%] = \frac{1}{2}(1 - \cos \beta_0)$

Figure 5.5: Virtual Coverage Movement

Shows how coverage area moves as satellite orbits while Earth rotates.

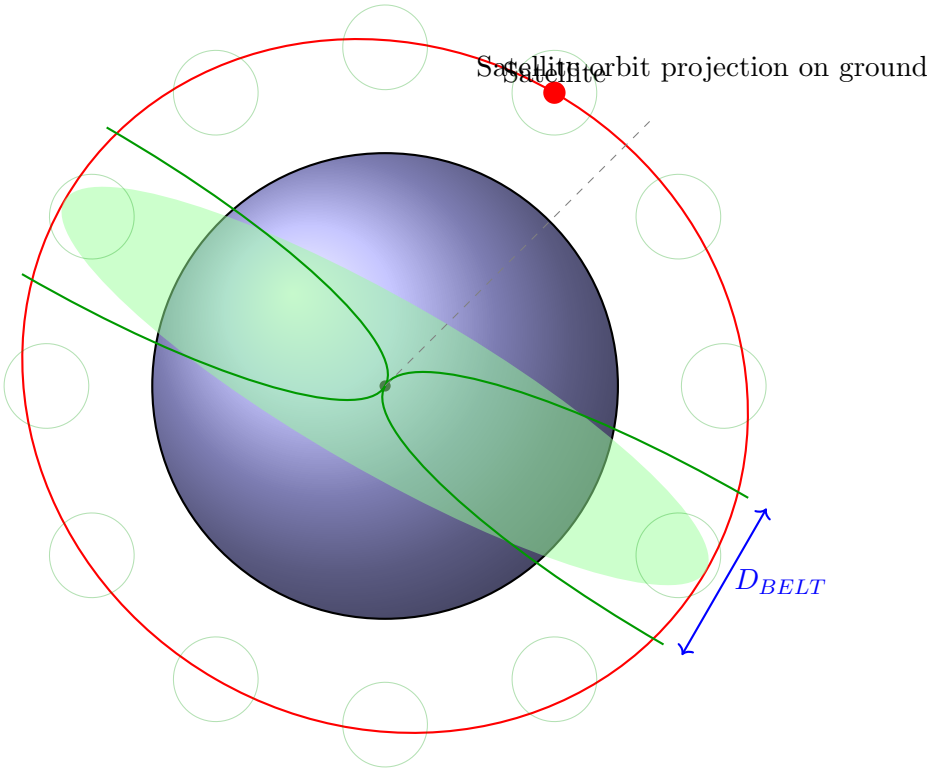


Key Concepts:

- Coverage footprint moves vertically along satellite's orbital path
- Earth rotates horizontally (eastward) around N-S axis
- Coverage belt moves westward relative to Earth's rotation
- Single satellite provides global access but not simultaneously

Figure 5.6: Coverage Belt

The area swept by satellite's coverage during one complete orbit.



Coverage Belt Width:

$$D_{BELT} = 2d_{max}$$

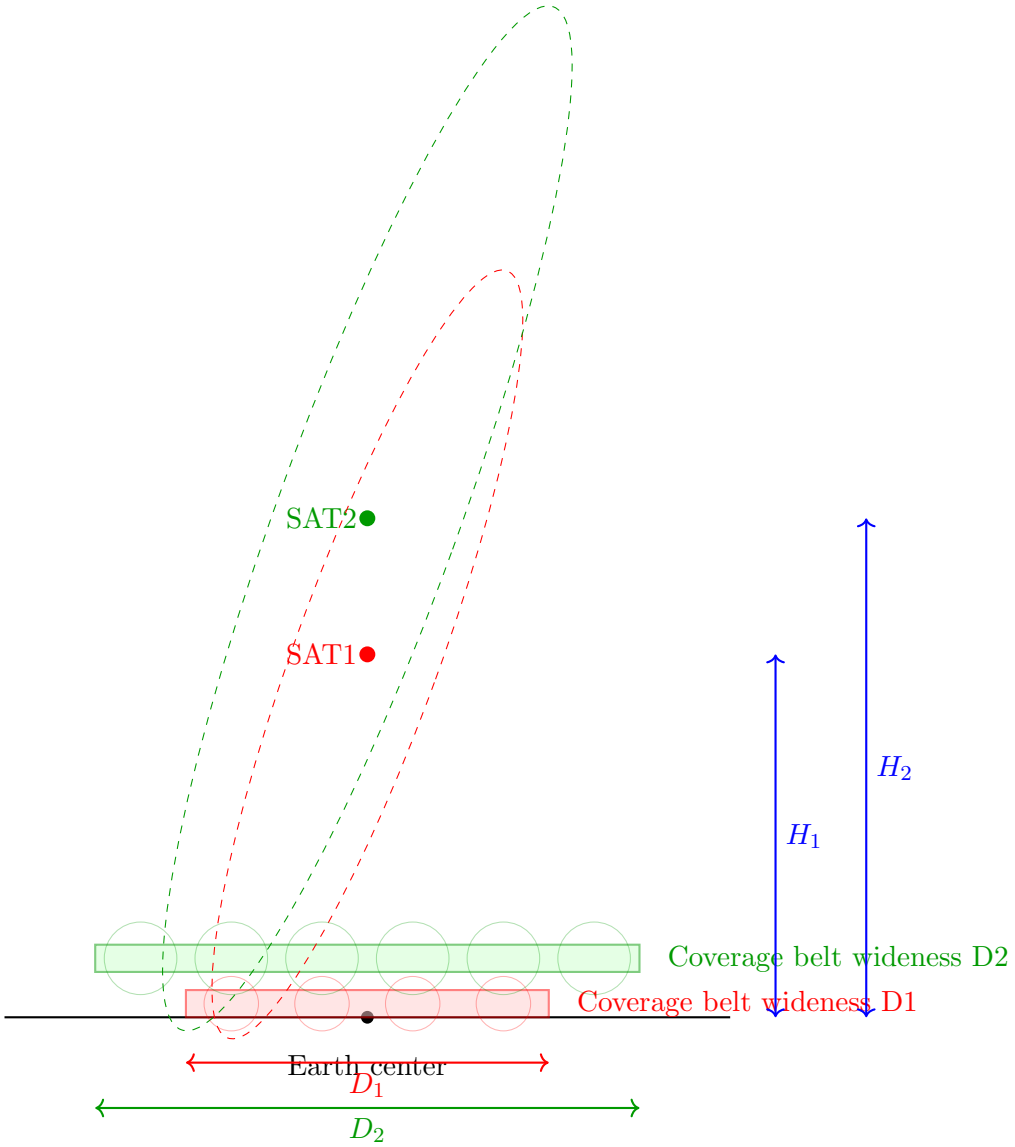
$$d_{max} = R_E \left[\sqrt{\left(\frac{H + R_E}{R_E} \right)^2 - 1} \right]$$

Key Points:

- Belt width depends on altitude H and elevation angle ε_0
- Wider at higher altitudes
- Narrower at higher elevation angles
- Range: 3857 to 8178 km for typical LEO altitudes

Figure 5.8: Coverage Belt of Different Satellite Altitudes

Comparison showing how altitude affects coverage belt width.

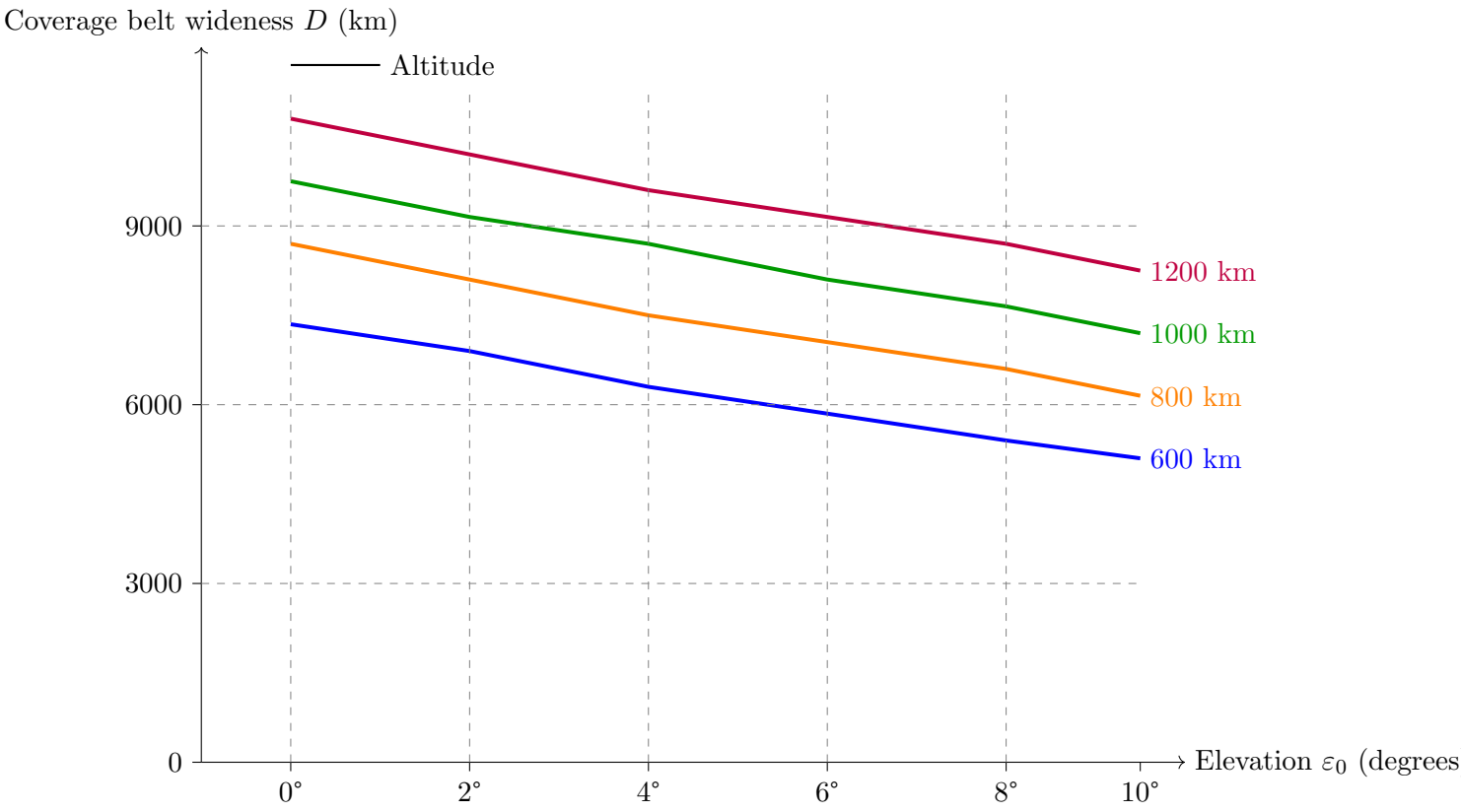


Relationship:

- Higher altitude ($H_2 > H_1$) → Wider coverage belt ($D_2 > D_1$)
- SAT2 at 1200 km: $D_{BELT} = 8177.8$ km (at $\varepsilon_0 = 0$)
- SAT1 at 600 km: $D_{BELT} = 5633.0$ km (at $\varepsilon_0 = 0$)

Figure 5.9: Coverage Belt Variation Graph

Shows how coverage belt width varies with elevation angle for different altitudes.

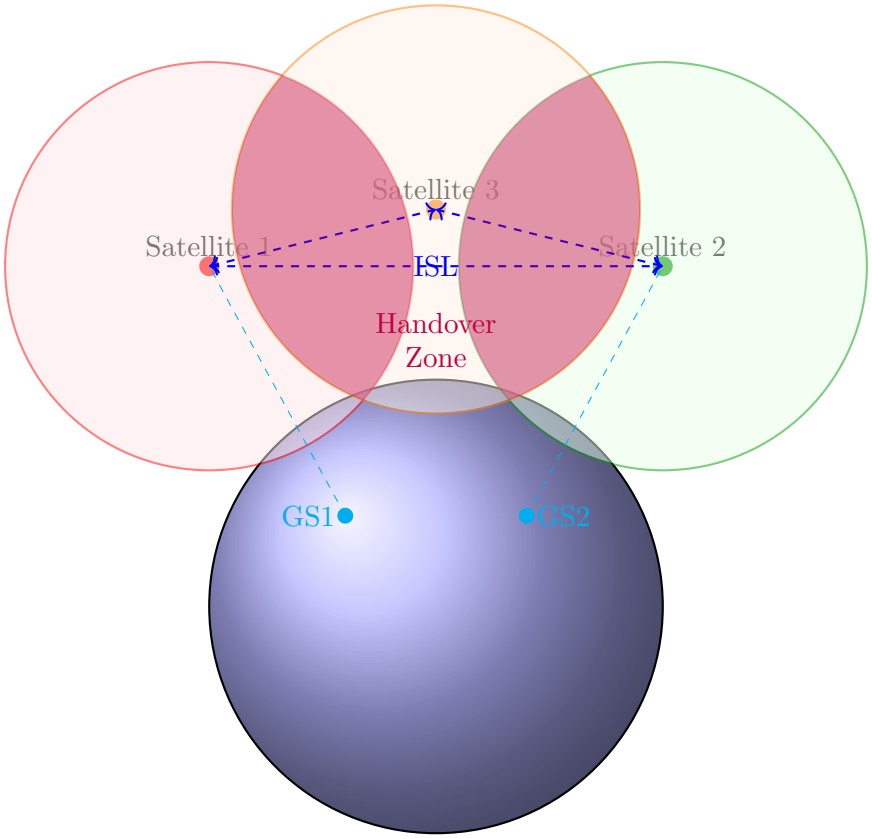


Key Observations:

1. All curves decrease as elevation increases (narrower belt at higher elevation)
2. Higher altitude curves are above lower altitude curves (wider belts)
3. Steepest decrease occurs at low elevations (0-4°)
4. At 10° elevation, belt widths range from 3857 km (600km) to 6274 km (1200km)

Figure 5.12: LEO Overlapped Coverage Area

Constellation with overlapping coverage zones for handover.

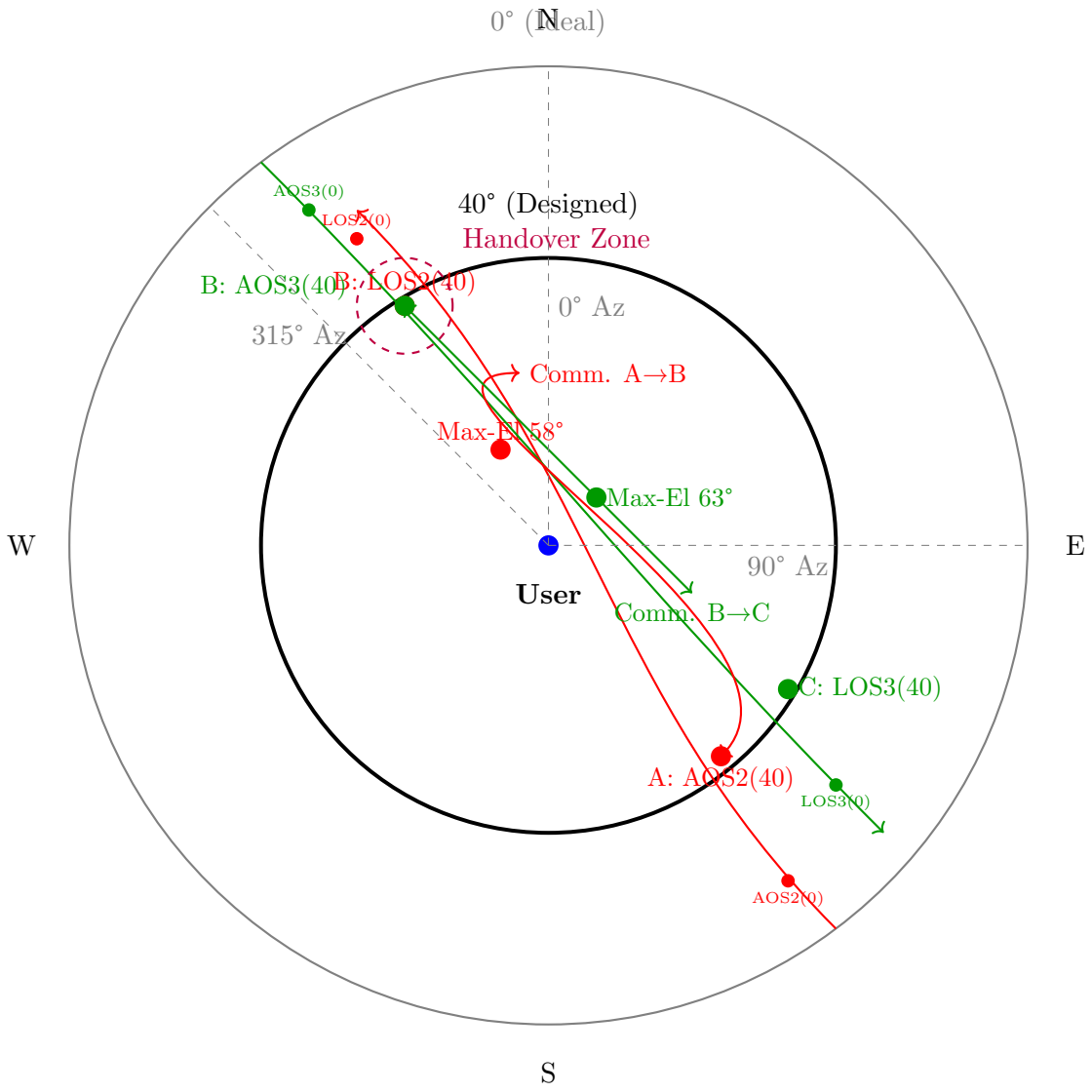


Key Features:

- Multiple satellites with overlapping coverage
- Purple regions show overlap zones (typically 2-5° overlap)
- ISL (Intersatellite Links) enable satellite-to-satellite communication
- Handover occurs in overlap zones
- User experiences seamless transition between satellites

Figure 5.14: Handover-Takeover Process (Radar Map View)

Geometrical confirmation of handover process showing acquisition/loss points.



Key Events and Coordinates (from Table 5.5):
Orbit2 (red):

- AOS2(0): [155°, 0°] - enters ideal horizon, not locked
- **Point A - AOS2(40): [220°, 40°]** - locked, comm starts, range = 809.5 km
- Max-El: [310°, 58°] - closest approach, range = 641.4 km
- **Point B - LOS2(40): [345°, 40°]** - unlocked, comm ends, range = 809.5 km
- LOS2(0): [30°, 0°] - leaves ideal horizon

Orbit3 (green):

- AOS3(0): [315°, 0°] - enters ideal horizon, not locked
- **Point B - AOS3(40): [345°, 40°]** - locked, comm starts, range = 809.5 km

- Max-El: [30°, 63°] - closest approach, range = 611.2 km
- **Point C - LOS3(40): [85°, 40°]** - unlocked, comm ends, range = 809.5 km
- LOS3(0): [125°, 0°] - leaves ideal horizon

Handover at Point B:

- Sat2 at 39° elevation: 827.9 km from user (ready to handover)
- Sat3 at 41° elevation: 800.6 km from user (ready to takeover)
- Distance between satellites: 40 km (can communicate via ISL)
- User maintains continuous communication: A $\rightarrow$ B $\rightarrow$ C

Summary of Key Geometric Concepts

1. Coverage Area

- Circular footprint on Earth's surface
- Determined by altitude H and elevation angle ε_0
- Larger at higher altitudes and lower elevations
- Typical LEO coverage: 1.69% to 7.95% of Earth

2. Coverage Belt

- Strip of Earth swept during one orbit
- Width = $2d_{max}$ where $d_{max} = R_E\sqrt{((H + R_E)/R_E)^2 - 1}$
- Range: 3857 to 8178 km for typical LEO altitudes
- Moves westward as Earth rotates eastward

3. Global Coverage

- Requires constellation of multiple satellites
- Coverage areas overlap by 2-5°
- Satellites intercommunicate via ISL
- Handover ensures continuous service

4. Handover Process

- Occurs in overlap zones
- LOS of one satellite coincides with AOS of another
- Satellites coordinate via ISL
- Seamless for user (no service interruption)