Chapter 4: Visual Companion Guide

Actual Diagrams for Key Figures

Visual Learning Supplement

October 11, 2025

This guide contains the most important visual diagrams from Chapter 4. The diagrams are:

- Figure 4.1: Keplerian Orbital Elements (3D view)
- Figure 4.7: Ideal Horizon Plane Geometry
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- Figure 4.14: 3D Geometry - Ideal and Designed Horizon Planes
- Figure 4.18: Link Budget Flow Diagram

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1 Figure 4.1: Keplerian Orbital Elements

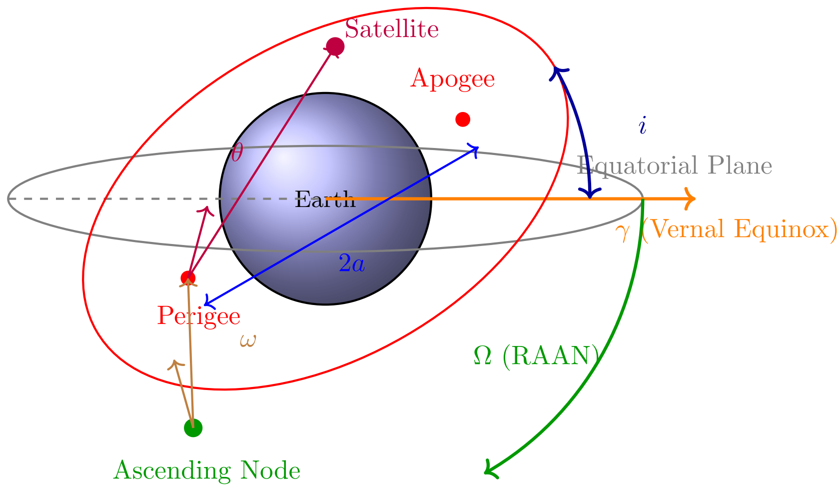

Figure 1: Six Keplerian orbital elements: semi-major axis a, eccentricity e, inclination i, RAAN Ω, argument of perigee ω, and true anomaly θ

Key Elements:

- a: Semi-major axis - determines orbital period
- e: Eccentricity - shape of ellipse (0=circle, ¡1=ellipse)
- i: Inclination - tilt of orbital plane (0-180°)
- Ω: RAAN - orients ascending node to vernal equinox
- ω: Argument of perigee - positions closest approach
- θ: True anomaly - satellite's current position in orbit

2 Figure 4.7: Ideal Horizon Plane Geometry

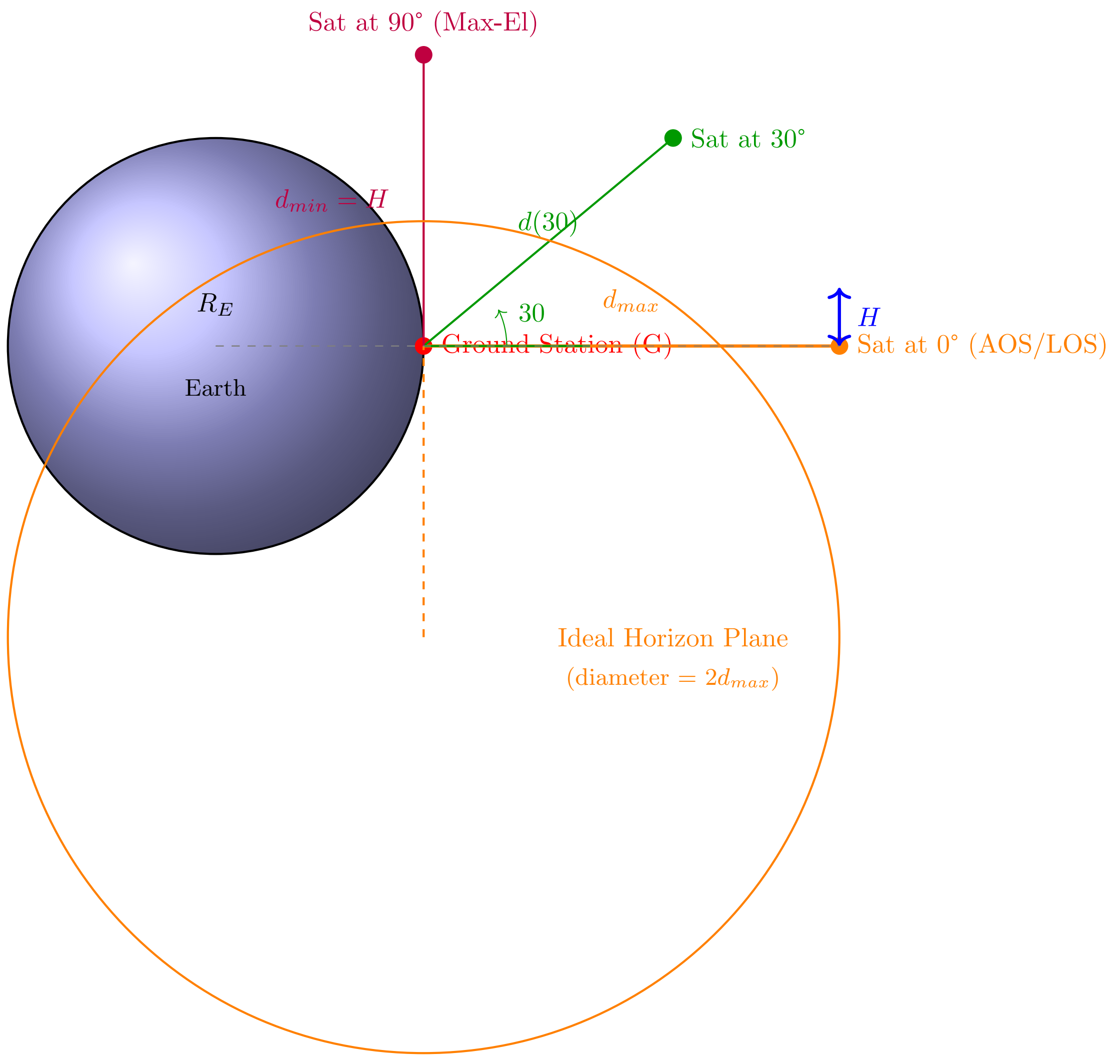

Figure 2: Ideal horizon plane showing slant range d varying with elevation angle. At 0° elevation, $d_{max} = \sqrt{H(2R_E + H)}$ defines the horizon plane radius.

Key Relationships:

- At $\epsilon_0 = 0$: $d_{max} = \sqrt{H(2R_E + H)}$ (horizon)
- At $\epsilon_0 = 90$: $d_{min} = H$ (overhead)
- Horizon plane diameter: $D = 2d_{max}$
- Higher altitude H creates wider horizon plane
- Communication duration depends on Max-El

3 Figure 4.11: Practical Horizon Plane (Broken Circle)

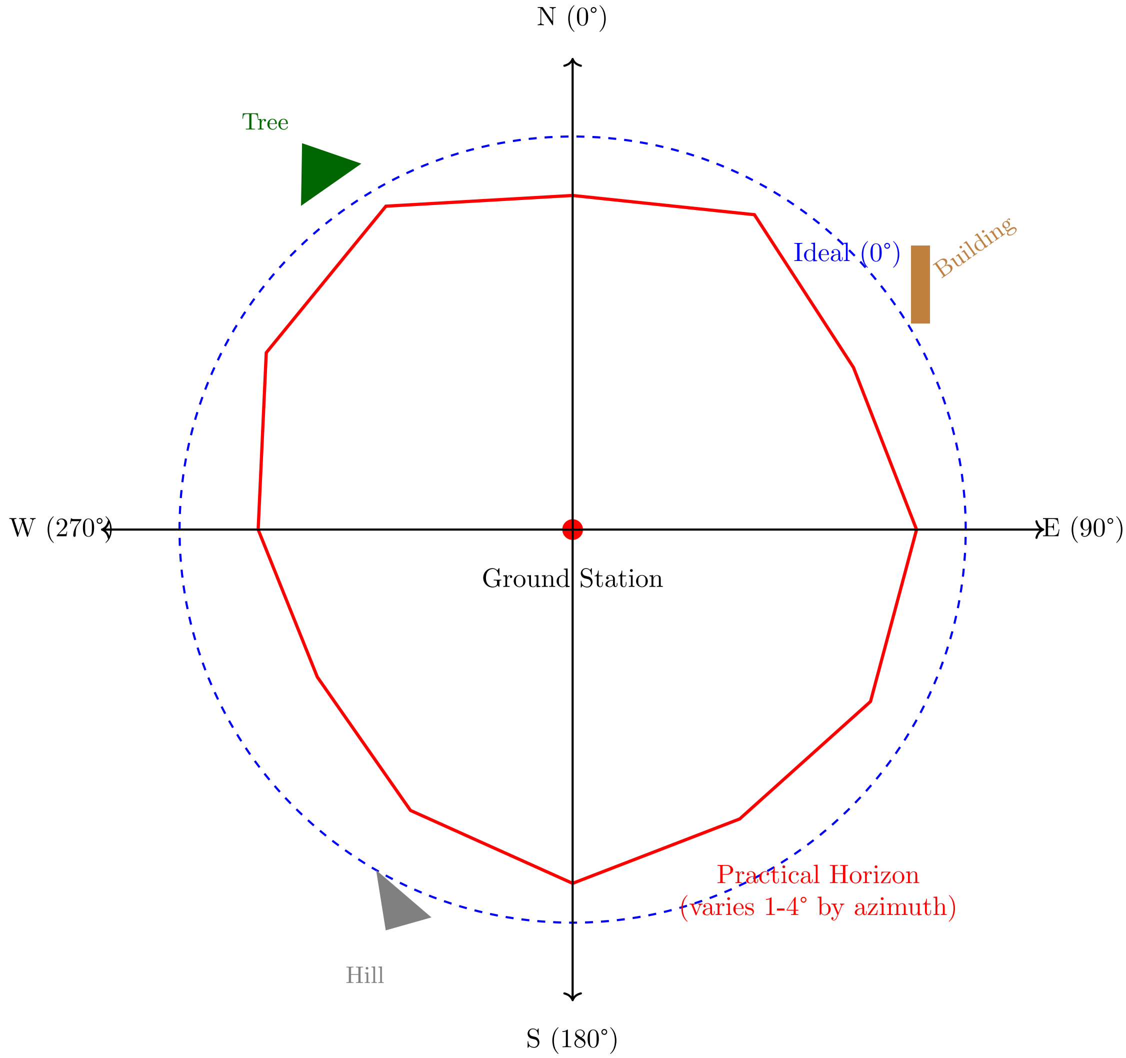

Figure 3: Practical horizon plane showing irregular boundary due to barriers (buildings, trees, terrain). The broken circle represents actual lock/unlock elevations by azimuth direction.

Key Differences from Ideal:

- Barriers raise effective horizon to 1-4° instead of 0°
- Lock/unlock elevations vary by azimuth direction
- Reduces communication duration by 5-20% vs ideal
- Urban stations more affected than rural sites
- Must be measured empirically for each site

4 Figure 4.14: 3D Geometry - Ideal and Designed Horizon Planes

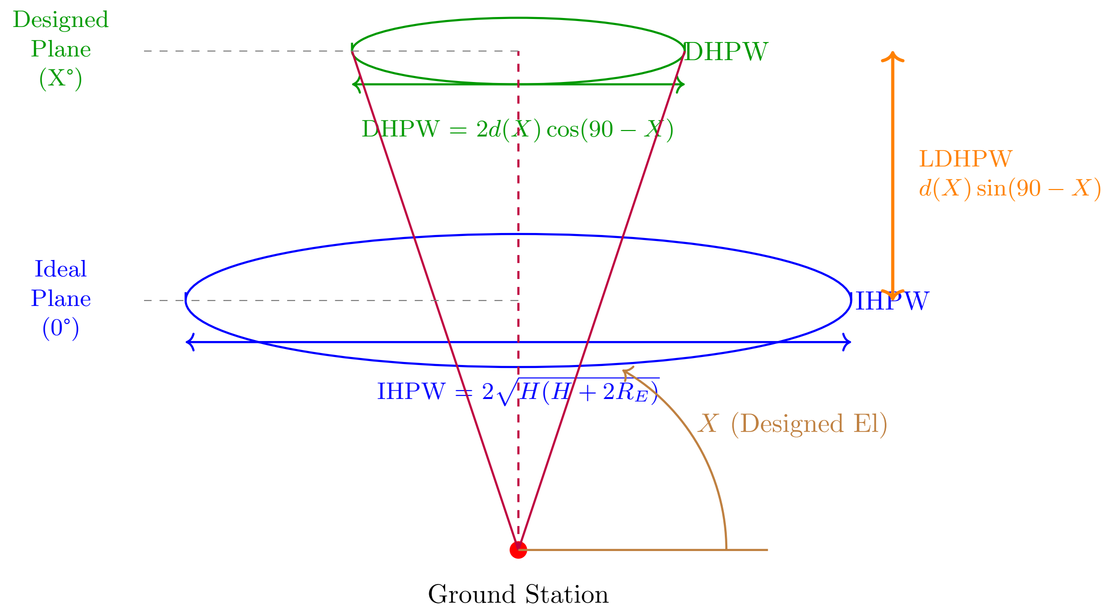

Figure 4: 3D geometry showing parallel ideal and designed horizon planes. The designed plane is elevated and has smaller diameter. LDHPW is the vertical separation between planes.

Key Parameters:

- IHPW: Ideal Horizon Plane Width (at 0° elevation)
- DHPW: Designed Horizon Plane Width (at X° elevation)
- LDHPW: Layer Distance between the two planes
- As designed elevation X increases:
  - DHPW decreases (smaller coverage circle)
  - LDHPW increases (planes separate more)
  - Power savings increase (shorter max range)
  - Communication duration decreases
- Critical for Starlink-like constellation design

5 Figure 4.18: Link Budget Flow Diagram

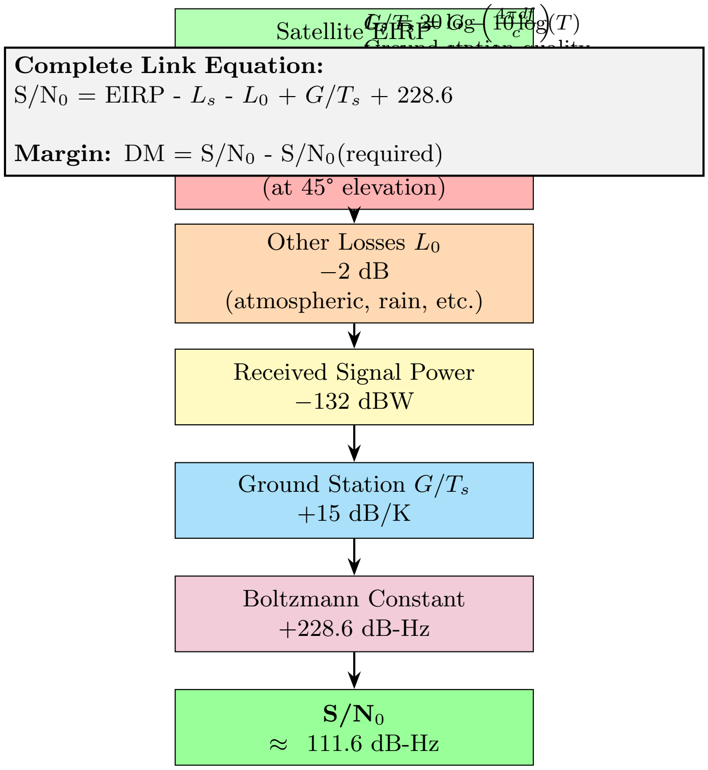

Figure 5: Link budget flow showing signal power progression from satellite transmitter to ground receiver. Each component contributes to or degrades the final S/N$_0$ ratio.

Component Explanation:

- **EIRP**: Effective Isotropic Radiated Power (transmit power $\times$ antenna gain)
- L_s: Free space loss - increases with distance d and frequency f
- L_0: Other losses - atmosphere, rain fade, polarization mismatch
- G/T_s: Ground station figure of merit (antenna gain / system noise temperature)
- **228.6**: Boltzmann's constant in dB-Hz (-228.6 dBW/K/Hz)
- **S/N$_0$**: Final signal-to-noise density ratio used to calculate data rate