USER MANUAL

Orbit Studio

Profile Generator for the SCE-C4202 Satellite Channel Emulator

Version 0.24 beta (rev.24) | Document rev. 1.0 | November 2026 | MantisTech (Mantis Technology Co., Ltd.)

Orbit Studio is a Windows application by **MantisTech (Mantis Technology Co., Ltd.)**. Its **Profile Generation** function is made for the **SCE-C4202 Satellite Channel Emulator**: it models satellites and terminals on a 3D globe and writes the time-varying **Delay / Frequency Offset (FO) / Gain** of the satellite–terminal link as the three CSV profiles that the SCE-C4202 Profile mode reads.

Besides profile generation, Orbit Studio provides 24-hour service analysis, handover and inter-satellite link (ISL) route analysis, a simple radiation dose (TID) estimate and real-time UDP output of positions and link states.

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1. Overview

The SCE-C4202 applies delay, frequency offset and gain to an RF signal in real time. In its **Profile mode** these three values change over time according to CSV profile files loaded from USB memory. Orbit Studio computes those files from real orbital geometry so that a satellite pass, a GEO link or a moving terminal can be reproduced on the bench.

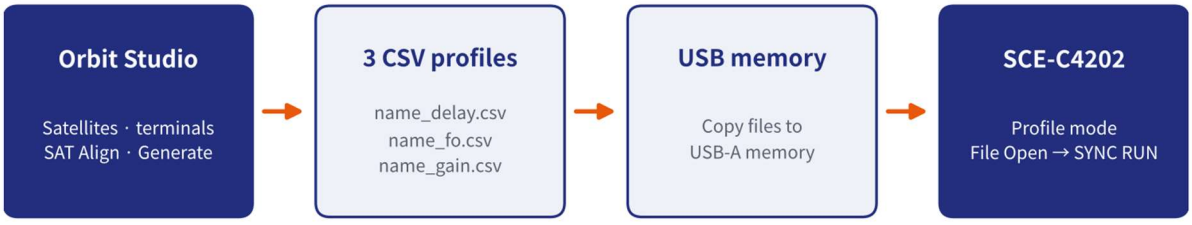


Figure 1. Workflow from Orbit Studio to the SCE-C4202

Item	Description
Product	Orbit Studio
Version	0.24 beta (rev.24). Format: 0.<rev> beta
Developer	MantisTech (Mantis Technology Co., Ltd.), www.mantistech.co.kr
Target equipment	SCE-C4202 Satellite Channel Emulator — Profile mode (Delay / FO / Gain)
Link model	One-way, satellite ↔ terminal, one selected satellite per profile
Coordinate system	WGS84 ellipsoid; all times in UTC

Item	Description
Orbits	LEO/MEO from TLE (SGP4) or user-defined orbits; GEO by longitude (fixed or 8-figure); space limited to 40,000 km altitude
Platform	Windows 10/11 64-bit

2. Key Features

- **SCE-C4202 profile output** — `name_delay.csv`, `name_fo.csv`, `name_gain.csv` in the SCE-C4202 template format, with automatic check of the emulator limits (rows, period, change per 1 ms, value range).
- **SAT Align** — jumps to the start of the pass in which the selected satellite flies (almost) directly over the terminal, searched within ±720 h.
- **Satellites** — TLE files (e.g. CelesTrak), Walker Delta/Star constellations, GEO with multiple aimed beams and 8-figure motion.
- **Moving terminals** — waypoint table with path smoothing and acceleration/deceleration; 12 icon types; terminal motion is included in the Doppler.
- **3D globe** — Natural Earth coastlines, borders and cities with automatic level of detail; FOV footprints, orbits, ground tracks, links and handover blinking.
- **Analysis** — 24-hour service statistics per terminal: visible satellites, path loss, elevation, Doppler, Doppler rate, delay, azimuth, off-axis angle and handovers; CSV export.
- **ISL route** — minimum-delay route between two terminals through inter-satellite links (Dijkstra), with per-hop processing delay.
- **Radiation (TID)** — simple AE8/AP8 total ionizing dose vs. aluminium shielding; IRENE (AE9/AP9) input file export.
- **UDP output** — positions, handover states and ISL routes over Ethernet (broadcast / multicast / unicast), 100–1000 ms.

3. Installation and Start-up

Orbit Studio is distributed as a single Windows installer (`OrbitStudio_Setup_0.24.exe`). The installer contains the program, all required libraries, the map data and the radiation (TID) module, so **Python or any other software does not need to be installed** and no internet connection is required.

3.1 System requirements

Item	Requirement
OS	Windows 10 / 11, 64-bit
CPU / RAM	x64, 4 cores or more recommended / 8 GB or more recommended
Disk space	About 500 MB for the program and map data
Display	1600 × 900 or larger recommended; OpenGL not required
Account	Administrator rights for installation only
Network	Not required. Ethernet adapter only for UDP output

3.2 Installation

1. Copy `OrbitStudio_Setup_0.24.exe` to the PC and double-click it. If Windows asks for permission (User Account Control), click **Yes**.
2. If Windows SmartScreen shows "Windows protected your PC", click **More info → Run anyway** (shown for new software that is not yet widely installed).
3. Read and accept the license agreement, then click **Next**.
4. Choose the installation folder (default `C:\Program Files\MantisTech\Orbit Studio`) and click **Next**.

5. Select additional tasks: **Create a desktop shortcut** (start-menu entry is always created), then click **Install**.
6. When installation finishes, leave **Launch Orbit Studio** checked and click **Finish**.

3.3 Start-up

Start Orbit Studio from the desktop shortcut or **Start menu > MantisTech > Orbit Studio**. A splash screen with the program name, version and company is shown for about 3 s, then the main window opens. **Help > About** shows the version (0.24 beta) and copyright.

Location	Contents
Installation folder	`OrbitStudio.exe`, libraries, `data` (map data), `tools` (UDP test receiver), `docs` (this manual, PROTOCOL.md, `orbit_studio_udp.h`), `THIRD_PARTY_NOTICES.txt`
User settings	`%APPDATA%\MantisTech\Orbit Studio` — `user_settings.json`, `net_settings.json`, recent files, window layout (kept per Windows user)
Scenario files	Any folder you choose (default: Documents)

3.4 Update and uninstall

- **Update**: run the installer of the new version. The previous version is replaced; settings in `%APPDATA%` and your scenario files are kept. Files saved with earlier revisions can be opened.
- **Uninstall**: Windows **Settings > Apps > Installed apps > Orbit Studio > Uninstall**, or **Start menu > MantisTech > Uninstall Orbit Studio**. User settings in `%APPDATA%\MantisTech\Orbit Studio` remain; delete the folder to remove them completely.
- **Restore default settings**: Tools > Options > Restore Defaults, or delete `user_settings.json` in the user settings folder.

※ Some antivirus programs scan new executables on first start, which can make the first start take longer. If the program is blocked, ask your IT administrator to allow `OrbitStudio.exe`.

4. Screen Layout and Controls

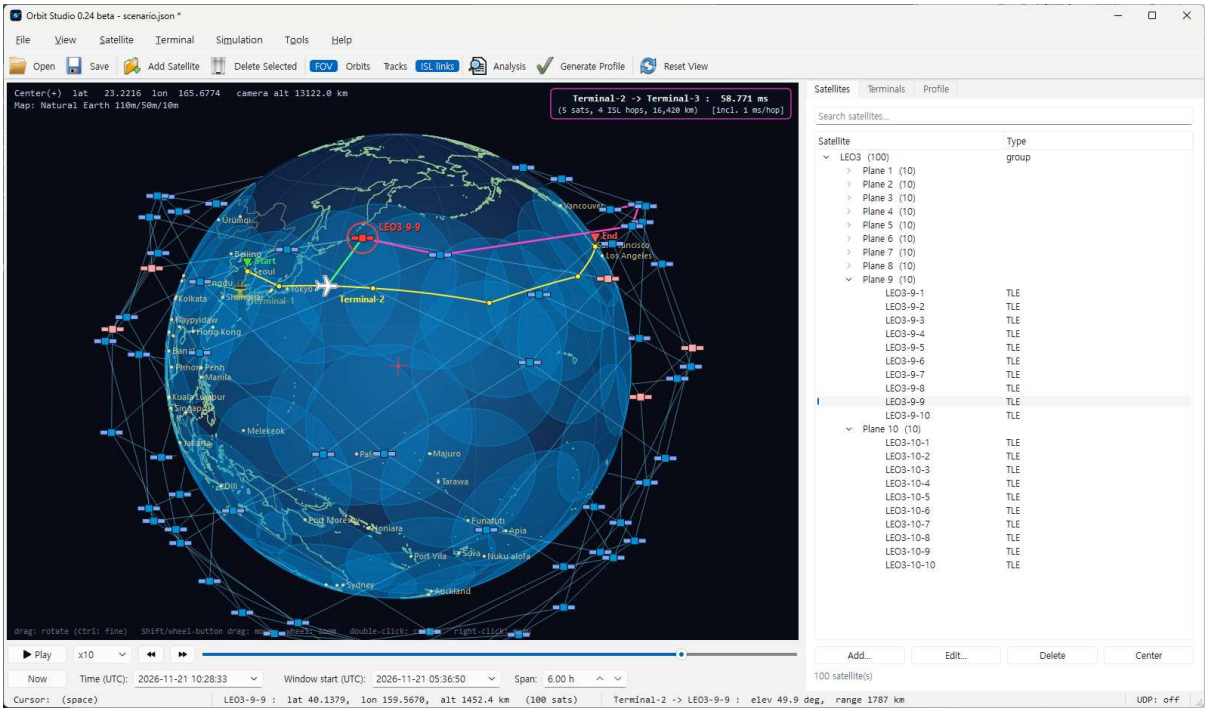


Figure 2. Orbit Studio main window — 100-satellite constellation, ISL route between two terminals and a moving aircraft

Area	Contents
Menu	File / View / Satellite / Terminal / Simulation / Tools / Help

Area	Contents
Toolbar	[Open][Save] | [Add Satellite][Delete] | [FOV][Orbits][Tracks][ISL links] | [Analysis][Generate] | [Reset View]
Left	3D globe; time slider with Play, speed, ±60 s; Now, Time (UTC), Window start, Span
Right tabs	Satellites (tree list) | Terminals (ISL path terminals + terminal table) | Profile (Profile parameters)
Status bar	Cursor coordinates, selected satellite position, selected terminal link, messages, UDP state (right)

4.1 Mouse

Action	Operation
Rotate view	Left drag (Ctrl + drag = 1/10 speed)
Pan	Shift + left drag, or middle-button drag
Zoom	Wheel, toward the cursor (option: Ctrl + wheel only)
Double-click	Center that point and zoom in two steps
Click / hover	Select satellite or terminal / tooltip with name, latitude, longitude, altitude
Right-click	Context menu: edit/delete satellite, add/delete beam, add/delete terminal point

4.2 Keyboard shortcuts

Key	Function	Key	Function
Ctrl+N / O / S	New / Open / Save	Ctrl+Shift+S	Save As
Ctrl+1 … 4	FOV / Orbits / Tracks / ISL	Ctrl+0	Reset view
Ctrl+E	Center selected satellite	F11	Full screen
Ctrl+Shift+N	Add satellite	F2 / Del	Edit / delete selected satellite
Space	Play / Pause	[/]	Speed down / up
Ctrl+← / →	−60 s / +60 s	Home	Go to now
Ctrl+T	Time input	Ctrl+Shift+A	SAT Align
Ctrl+G	Generate	F5	Analysis
Ctrl+,	Options	F1	User guide

※ F2, Del and Home act on satellites only when the globe or the satellite list has focus (they keep their table meaning in the terminal table).

4.3 Time

All times are UTC. Drag the slider or type `2026-11-16 05:10:00` in **Time (UTC)** and press Enter. The slider range is set by **Window start** and **Span**; **Now** moves both to the current time. Play speeds: ×1, ×10, ×60, ×300, ×1800.

5. Satellites

Open **Satellite > Add Satellite** (Ctrl+Shift+N). Choose one of three tabs, then set the common items (FOV, constellation, ISL).

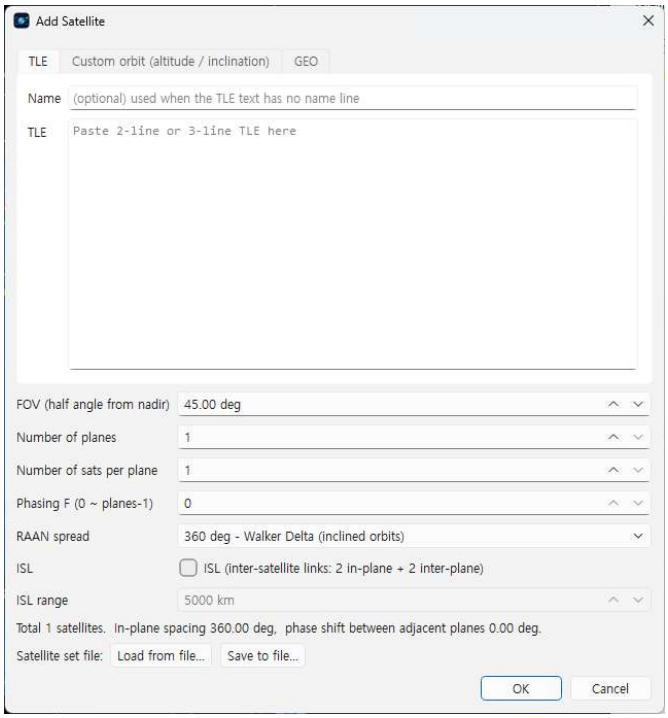


Figure 3. Add Satellite dialog (TLE tab)

Tab	Input	Notes
TLE	Two-line elements pasted or loaded from a text file (2-line / 3-line format)	Propagated with the standard SGP4 model. Most accurate for real satellites.
Custom orbit	Altitude, inclination, RAAN, phase; Walker constellation: planes P, satellites per plane S, phasing F, RAAN spread (360 = Delta, 180 = Star)	A TLE is generated from the altitude with Kepler's law (see §14).
GEO	Longitude; optional 8-figure motion (inclination, north-peak time; advanced: eccentricity, perigee time, drift)	35,786 km above the equator. i = 0 → fixed point.

5.1 Field of view (FOV)

FOV is a **half angle** measured from nadir: 45 means ±45° around the satellite's nadir direction. A satellite with FOV 0 cannot communicate. GEO beams use the beam aim direction as the axis.

Example: for a 550 km satellite, a nadir half angle of 65.0° corresponds to 10° elevation at the edge of the footprint. If the FOV is smaller, the FOV (not the service angle) limits the pass.

5.2 Satellite list and multi-edit

- The **Satellites** tab groups satellites named `name-plane-number` into constellation → plane → satellite; a search box filters the list.
- The selected satellite is drawn red with a ring and its name; satellites in the same orbital plane are drawn light red. It is the target of Generate and SAT Align.
- Ctrl/Shift + click or selecting a plane/constellation row, then **Edit…** (F2) changes FOV, ISL on/off, ISL range and color of all of them at once; **Delete** removes them after confirmation.
- **File > Import / Export Satellites** saves or adds satellites only (JSON or TLE text) without touching terminals.

Example — 96-satellite Walker Delta

Custom orbit tab: altitude 550 km, inclination 53°, P = 6, S = 16, F = 1, RAAN spread 360, FOV 50°. Orbit Studio creates 96 satellites named e.g. `WD-3-07` (plane 3, satellite 7) and groups them in the Satellites tab.

5.3 GEO beams and 8-figure motion

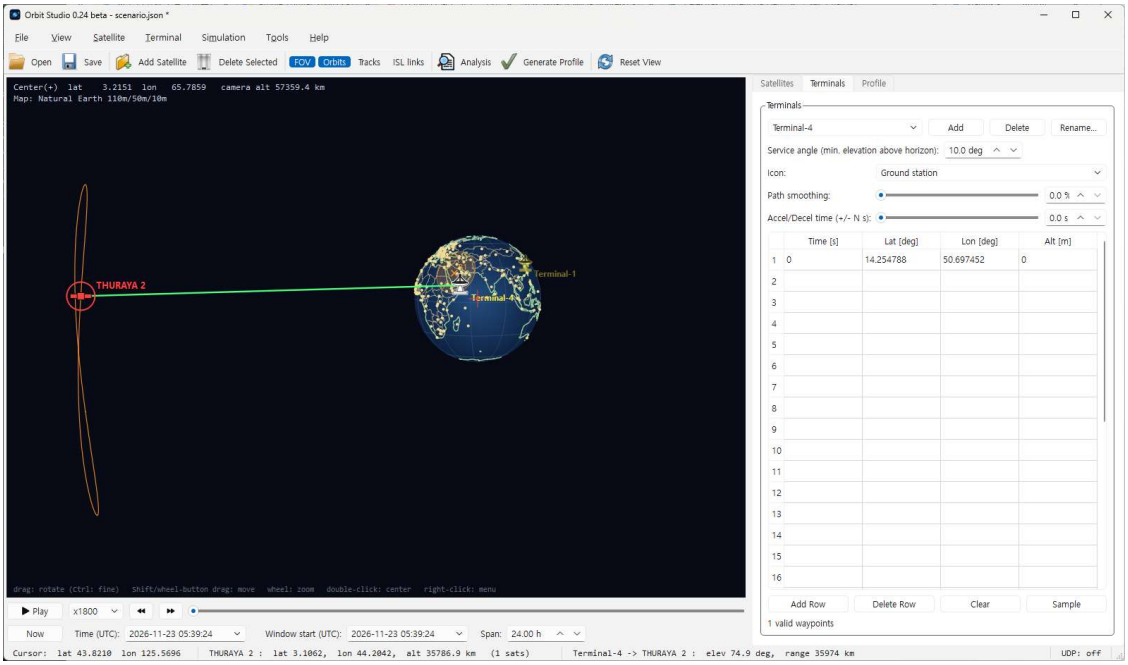


Figure 4. GEO satellite entered by TLE (THURAYA 2) with its daily 8-figure track (Orbits on)

- **Add beam**: select the GEO satellite, right-click the aim point on the globe → `Add beam of '…' aimed here…` → enter FOV. Delete by right-clicking the beam marker (B1, B2 …). A terminal inside any beam satisfies the FOV condition.
- TLE satellites with a mean motion of 0.9–1.1 rev/day are treated as GEO and can also have beams.
- **8-figure motion**: Inclination i [deg] is the north–south half width (latitude ±i); North-peak time is when the satellite is northernmost; the east–west half width ≈ $i^2/4$ [rad] is shown read-only (i = 5° → ±0.109°).
- With 8-figure motion, delay and FO vary with a one-day period (e.g. i = 3°, 2 GHz, terminal in Seoul → FO about ±110 Hz). With **Orbits** on, the daily 8-figure track is drawn on the globe.

6. Terminals

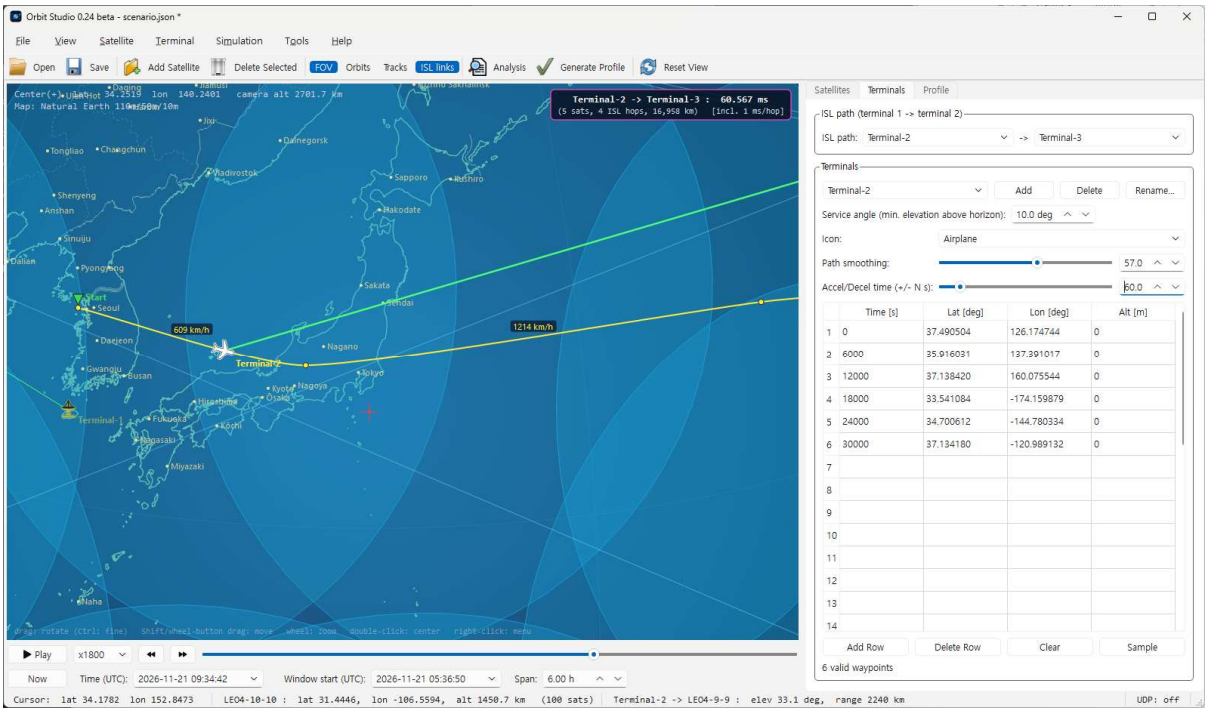


Figure 5. Terminals tab — aircraft terminal with 6 waypoints, Path smoothing 57 % and Accel/Decel 60 s; segment speeds on the map

Item	Description
Add / Delete / Rename	Buttons next to the list or the Terminal menu
Service angle	Minimum elevation [deg] at which the satellite is usable, per terminal
Path table	One row per waypoint: time [s], latitude, longitude, altitude [m] (above the WGS84 ellipsoid). Paste from Excel with Ctrl+V. One row = fixed terminal.
Points on the map	Right-click the surface → Add point; right-click a yellow point → Delete
Icon	Ground station, aircraft, helicopter, drone, missile, car, RV/truck, train, armored vehicle, warship, motorboat, handheld
Path smoothing [%]	0–100. 0 = straight segments with corners, 100 = smoothest curve (Catmull-Rom Hermite; always passes through every point)
Accel/Decel time [s]	0–600. Constant acceleration over ±N s around each point; the scheduled point times are kept

6.1 When does a terminal move?

Function	Time 0 of the path table
Generate / SAT Align	The moment communication with the selected satellite starts. Before that the terminal waits at the first point.
Globe (Play)	The moment Play is pressed. Typing a time, Now, SAT Align or Open returns terminals to the start (`waiting at start - press Play`).
Analysis	Start time of the analysis

After the last row the terminal stays at the last point. Zoomed in below 3,000 km camera altitude, the average speed of each segment (straight distance / time, km/h by default) is written at the segment midpoint.

Example — aircraft terminal

Time [s]	Latitude	Longitude	Alt [m]
0	37.46	126.44	0

Time [s]	Latitude	Longitude	Alt [m]
600	37.90	128.40	10000
1800	35.18	129.07	10000

With Path smoothing 50 % and Accel/Decel time 60 s, the aircraft takes off from Incheon, accelerates during the first 60 s, turns smoothly near the second point and decelerates to stop exactly at t = 1800 s. Its velocity is added to the Doppler of the profile.

7. Link Conditions and Handover Display

A satellite and a terminal can communicate when **both** conditions hold:

1. Elevation of the satellite seen from the terminal ≥ the terminal's Service angle.
2. The terminal is inside the satellite's FOV cone (or inside one of its GEO beams).

- Each terminal draws a green line to its **serving satellite** = the nearest usable satellite (thick for the selected terminal).
- A change of serving satellite is a handover: an orange dashed line blinks to the next satellite before it and to the previous satellite after it. Blink time depends on play speed (×1: 5 s, ×10: 3 s, ×60: 1.5 s, ×300: 1 s, ×1800: 0.8 s).
- Loss and later re-acquisition of service is not counted as a handover. Jumps of more than 10 minutes are not shown as handovers.

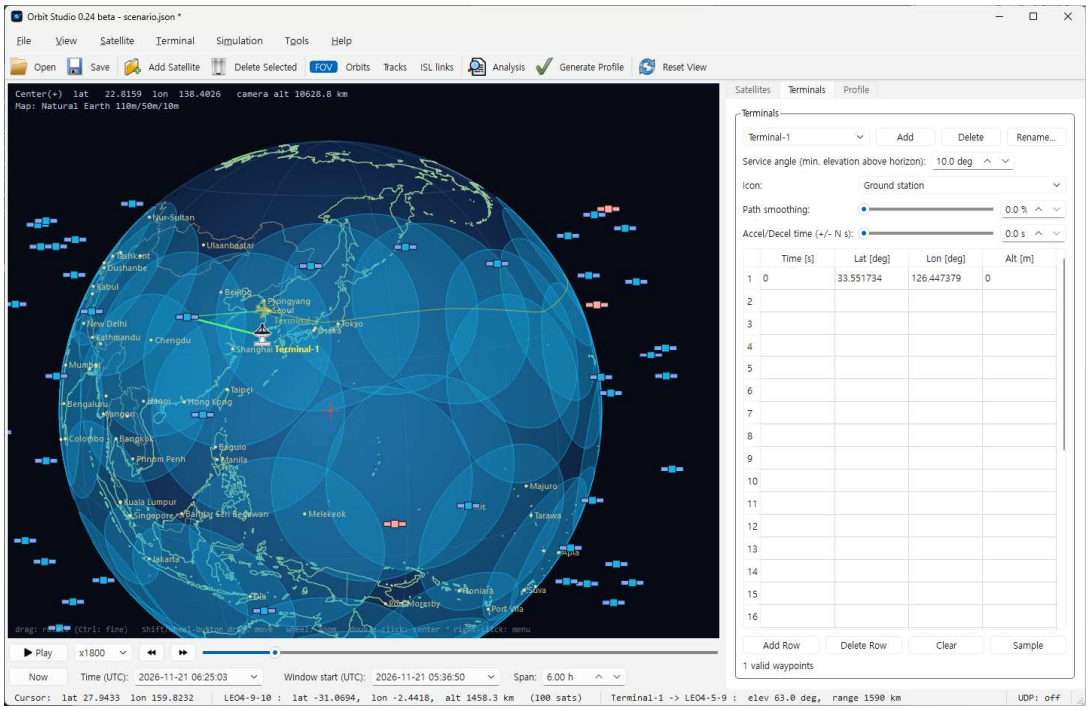


Figure 6. Ground-station terminal linked (green line) to its serving satellite; FOV footprints shown

※ The handover display is for visualization and analysis only. A generated profile always follows one selected satellite and does not include handovers.

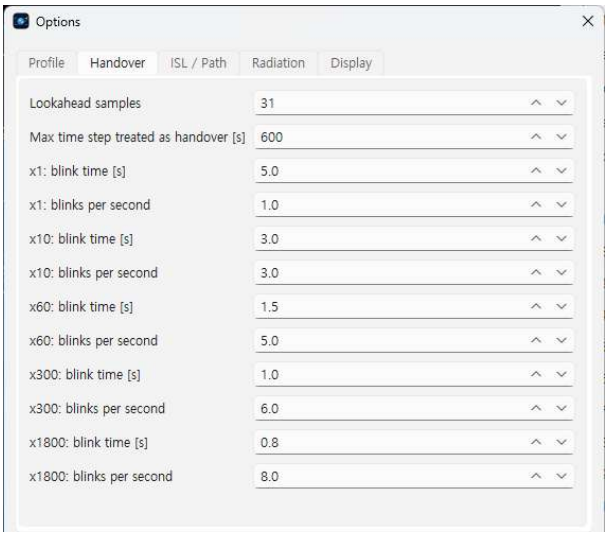


Figure 7. Options — Handover tab (blink time per play speed)

8. Profile Generation (SCE-C4202)

This is the main function of Orbit Studio for the SCE-C4202. Set the parameters in the **Profile** tab and press **Generate** (Ctrl+G).

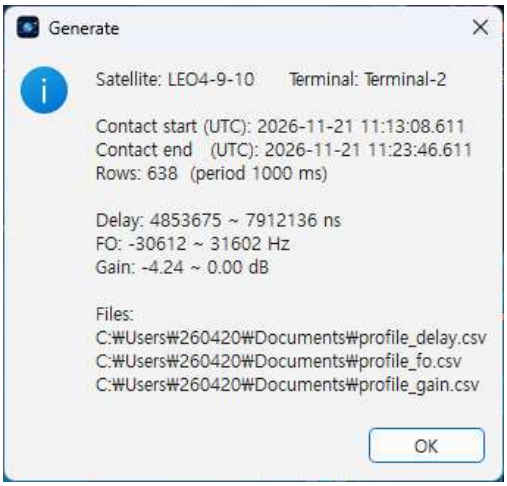


Figure 8. Generate result — contact start/end, rows, value ranges and the three file names

8.1 Parameters

Item	Description
Carrier frequency [MHz]	RF carrier of the simulated system, used for FO. It may differ from the emulator's 200–2100 MHz RF port frequency, because FO is applied as an offset.
Profile period [ms]	Time step of one CSV row. Default 1000 ms (60,000 ms when a GEO satellite is selected). Minimum 1 ms.
Duration [h] (GEO)	Enabled only for GEO satellites: length of the profile from the start of communication. Default 24 h.
Folder / File name	Output location and base name → `name_delay.csv`, `name_fo.csv`, `name_gain.csv`
Generate	From the current time, finds the first moment the selected satellite–terminal pair can communicate and writes the profile until the link is lost (LEO/MEO) or for Duration (GEO). If already in contact, it starts now. Search range 720 h.
SAT Align	Finds the pass closest to the current time whose peak elevation is ≥ 88° ("overhead") within ±720 h and moves to the start of communication of that pass. If none exists, it uses the highest pass and reports its peak elevation.

8.2 Typical procedure

1. Add the satellite(s) and the terminal; select the satellite in the Satellites tab and the terminal in the Terminals tab.
2. Press **SAT Align** (Ctrl+Shift+A) to move to an overhead pass (optional).
3. Enter Carrier frequency and Profile period; check that pass time ÷ period ≤ 8000.
4. Press **Generate** and read the result dialog (start/end time, rows, constraint warnings).
5. Copy the three CSV files to USB memory, insert it into the SCE-C4202 front USB port, select each file with **File Open** in Profile mode and start them together with **SYNC RUN** (the three files have the same length).



Figure 9. SCE-C4202 Profile tab — Delay / Frequency Offset / Gain files, RUN, SYNC and LOOP

8.3 Calculation

Profile	Formula	Notes
Delay [ns]	range / c	Integer ns
FO [Hz]	−f × (dR/dt) / c	Positive when approaching. dR/dt from range difference at t ± 0.5 s; includes terminal motion. Integer Hz.
Gain [dB]	20·log10(R_min / R)	Relative free-space loss; 0 dB at the shortest range of the profile, negative elsewhere. 0.01 dB.

To avoid accumulated rounding error, each row's change is the difference between two **rounded absolute values**, so the value reached after any number of rows equals the rounded exact value.

8.4 File format

Identical to the SCE-C4202 profile template: UTF-8 with BOM, CRLF line ends; row 1 `[Init_xxx](range),initial value`; row 2 column headers; from row 3 `change,period_ms`.

Row	name_delay.csv	name_fo.csv	name_gain.csv
1	[Init_Delay_ns](16000~500000000),7912136	[Init_FO_Hz](-10~10000000),31602	[Init_Gain_dB](-20.00~20.00),-4.24
2	[Delay_Change_ns],[Period_ms]	[FO_Change_Hz],[Period_ms]	[Gain_Change_dB],[Period_ms]
3	-15789,1000	-50,1000	0.01,1000
4	-15763,1000	-52,1000	0.02,1000
5	-15737,1000	-52,1000	0.02,1000
…	…	…	…

First rows of the files written for the example in §8.6 (period 1000 ms).

8.5 Equipment constraint check

Constraint	Value	If exceeded
Maximum rows	8000	Only the first 8000 rows are saved; the period needed for the whole pass is reported. For GEO a confirmation appears before generation.
Minimum period	1 ms	Smaller values cannot be entered
Max change per 1 ms	Delay ±100 ns, FO ±100 kHz, Gain ±10 dB	Number of violating rows is reported (file is still saved)
Value range	Delay 16 µs – 500 ms, FO ±10 MHz, Gain ±20 dB (SCE-C4202)	Warning

※ Some earlier SCE-C4202 documents state a maximum of 1024 profile lines. Orbit Studio uses 8000 rows (the value of the current emulator firmware). The limit can be changed in Tools > Options > Profile if your unit differs.

8.6 Worked example — LEO pass to a moving aircraft

Satellite LEO4-9-10 of a 100-satellite constellation at 1,450 km / 40°, terminal Terminal-2 (aircraft departing Seoul, Path smoothing 57 %, Accel/Decel 60 s, service angle 10°), carrier 2000 MHz, Profile period 1000 ms. After SAT Align, Generate produced the result below.

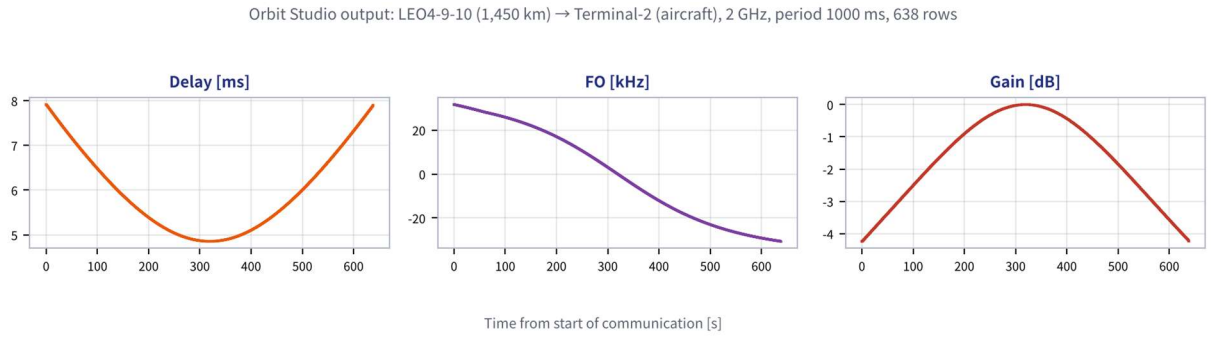


Figure 10. Delay, FO and gain profiles written by Orbit Studio (values reconstructed from the CSV files)

Quantity	Value	vs. SCE-C4202 limit
Contact (UTC)	2026-11-21 11:13:08.611 – 11:23:46.611 (638 s)	—
Rows	638 (1000 ms)	≤ 8000
Delay	4.854 – 7.912 ms	within 16 µs – 500 ms
FO	-30,612 – +31,602 Hz	within ±10 MHz
Gain	-4.24 – 0.00 dB	within ±20 dB
Largest change per row	Delay 15,789 ns, FO 159 Hz, Gain 0.02 dB	per 1 ms: 15.8 ns, 0.16 Hz — OK
Shortest period for one file	79.8 ms (638 s ÷ 8000)	e.g. 100 ms → 6,380 rows

Delay is shortest (and gain 0 dB) at about 319 s, when the satellite passes almost overhead. The small kink in the FO change at about 60 s is where the aircraft finishes its 60 s acceleration: the terminal's own velocity is part of the Doppler.

9. Analysis

Tools > Analysis (F5) computes 24 hours from the current time for **all terminals**. Choose the satellites (all / selected only) and the time step (Auto = 5 s, or 1 / 2 / 5 / 10 / 30 s). For every time the serving satellite is the nearest usable one; all values refer to it.

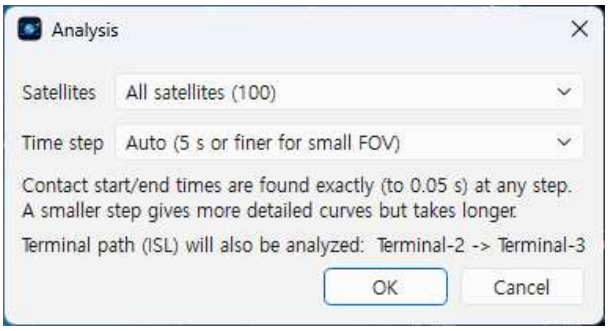


Figure 11. Analysis options — satellites and time step

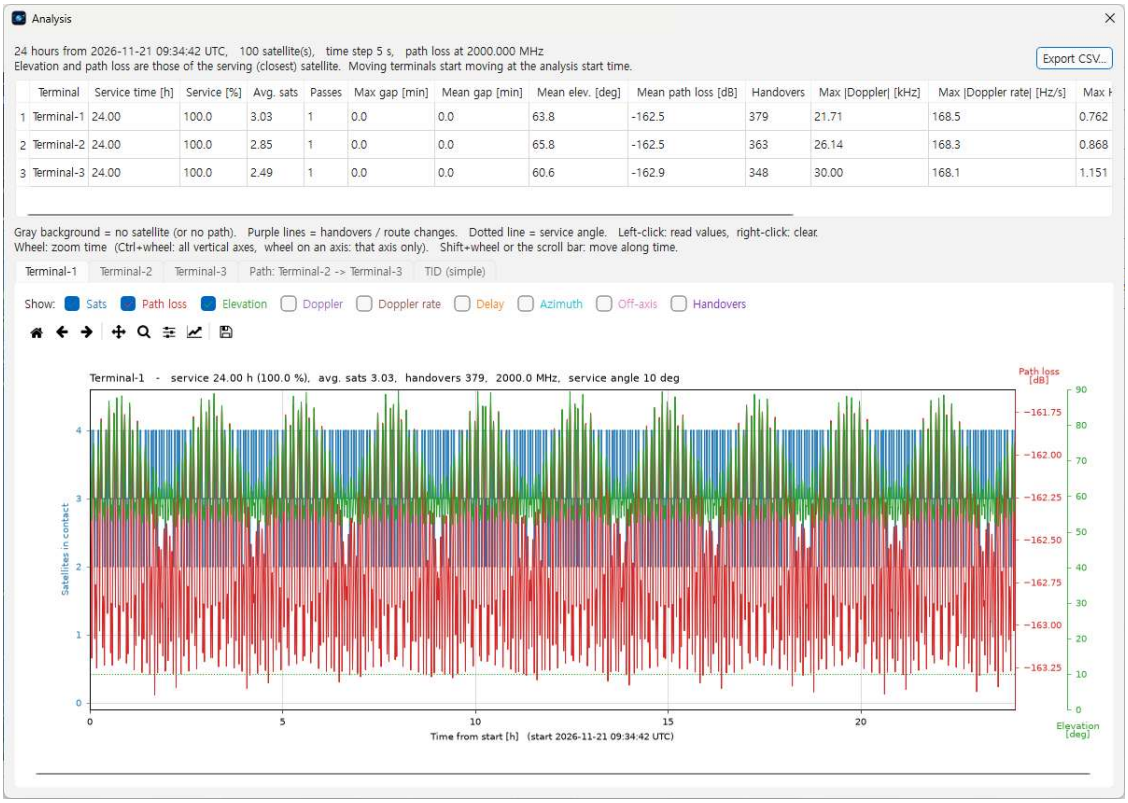


Figure 12. Analysis window — 24 h summary table and Terminal-1 graph (Sats, Path loss, Elevation)



Figure 13. The same graph zoomed to 30 minutes with Handovers on (purple lines)

Graph item	Meaning
Sats	Number of usable satellites (left axis)
Path loss	−20·log10(4πdf/c) [dB] with the Carrier frequency
Elevation / Azimuth	Look angles to the serving satellite (azimuth: N = 0°, E = 90°)
Doppler / Doppler rate	Same calculation as profile FO [kHz] / its rate [Hz/s]
Delay	One-way delay [ms]
Off-axis	Angle from FOV (beam) axis to the terminal; close to FOV = beam edge
Handovers	Vertical lines: `crossing` (another satellite became nearer; delay jump ≈ 0) or `dropout` (serving satellite left coverage)

- Start and end of coverage are located to 0.05 s regardless of the time step; the time step only affects curve density and whether contacts shorter than the step are found.
- Left click shows the values at that time; wheel zooms per axis (Ctrl + wheel: all vertical axes; Shift + wheel: scroll).
- Summary table: service time [h, %], average satellites, passes, longest/average outage [min], mean elevation and path loss, handovers, max |Doppler|, max |Doppler rate|, max delay/Doppler jump at handover.
- **Export CSV** writes `_summary.csv`, `_timeseries.csv`, `_handovers.csv` (and `_path.csv` for an ISL path).

※ Compared with the emulator limit of 100 ns per 1 ms, a `dropout` handover usually produces a delay jump far larger than one row allows. This is one reason profiles do not include handovers.

10. Radiation TID (Simple)

The **TID (simple)** tab of the Analysis window groups the analysed satellites by orbit (same inclination, perigee and apogee) and calculates the total ionizing dose for the mission.

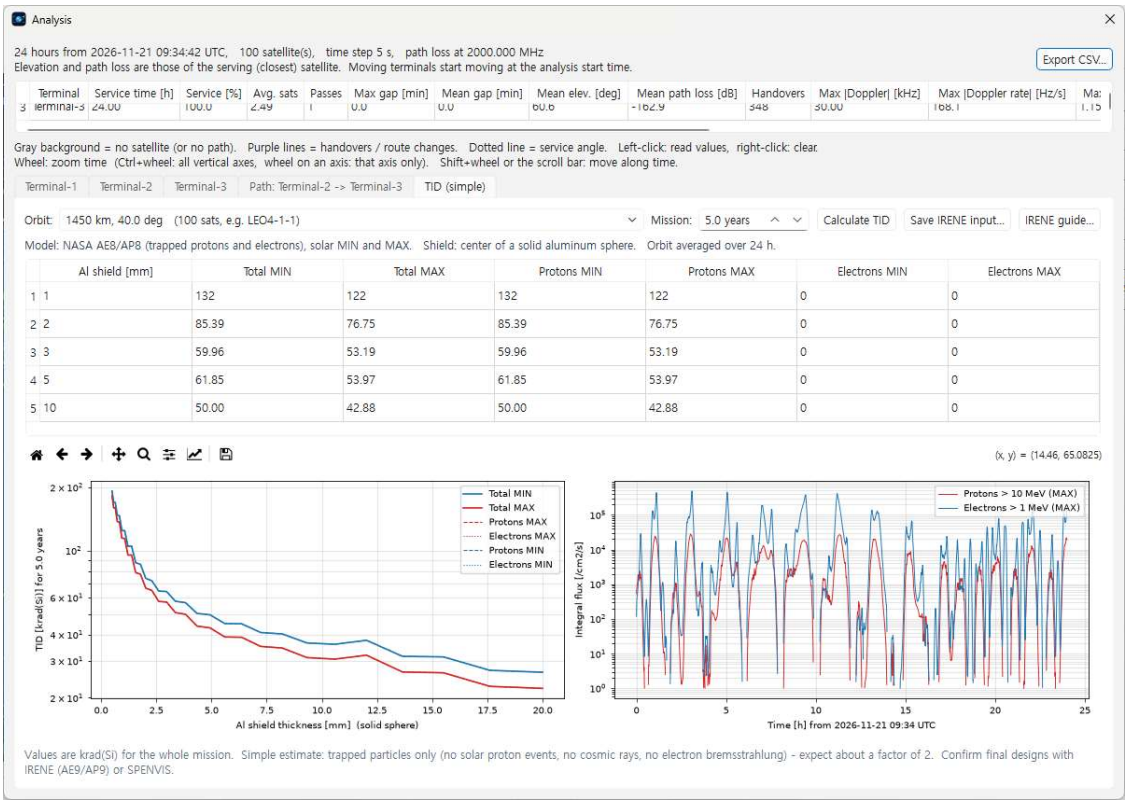


Figure 14. TID (simple) tab — 1,450 km / 40° orbit, 5-year mission

Item	Description
Mission	Mission duration [years], default 5
Table	Dose [krad(Si)] behind 1, 2, 3, 5, 10 mm Al: total / proton / electron, solar MIN and MAX
Graphs	Dose–depth curves; >10 MeV proton and >1 MeV electron flux along the orbit (SAA peaks in LEO)
Save IRENE input / IRENE guide	Writes ephemeris + AE9/AP9 input files for CmdLineIrene and explains how to run IRENE

Method: 24 h of orbit at 30 s steps → orbit-averaged AE8/AP8 integral flux (aep8: IRBEM, IGRF) → solid-sphere aluminium shielding using NIST PSTAR range tables for protons and the Katz–Penfold relation with ESTAR stopping power for electrons.

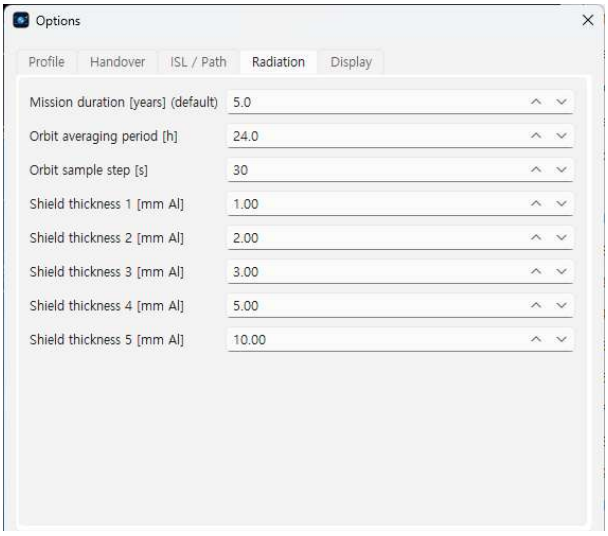


Figure 15. Options — Radiation tab

11. Inter-Satellite Links (ISL) and Terminal-to-Terminal Path



Figure 16. Analysis Path tab — satellites in the route and path delay Terminal-2 → Terminal-3 over 24 h

- Enable **ISL** and **ISL range** [km] in the Add/Edit Satellite dialog. Each satellite has up to 4 links: front and rear in the same plane, and one in each neighbouring plane.
- Orbital planes are detected automatically (plane normal within 3°, altitude within 50 km), so TLE files and generated constellations behave the same.
- Inter-plane links: fixed pairing (+Grid) when neighbouring planes have equal satellite counts, otherwise nearest pairing with 20 % hysteresis; disabled above 70° latitude and across the seam of counter-rotating planes.
- A link is alive when both satellites have ISL on, the distance ≤ the smaller ISL range and the line is not blocked by the Earth (80 km altitude).
- Select two terminals under **ISL path** in the Terminals tab: the minimum-delay route (Dijkstra) is drawn in pink, and delay, satellite count, hops and length are shown at the top-right. Delay = propagation + hops × 1 ms (default per-hop delay).
- The access satellites of both terminals are chosen by total path delay; they change only if another pair is ≥ 2 ms faster and the current pair has been used ≥ 30 s (or the path breaks).

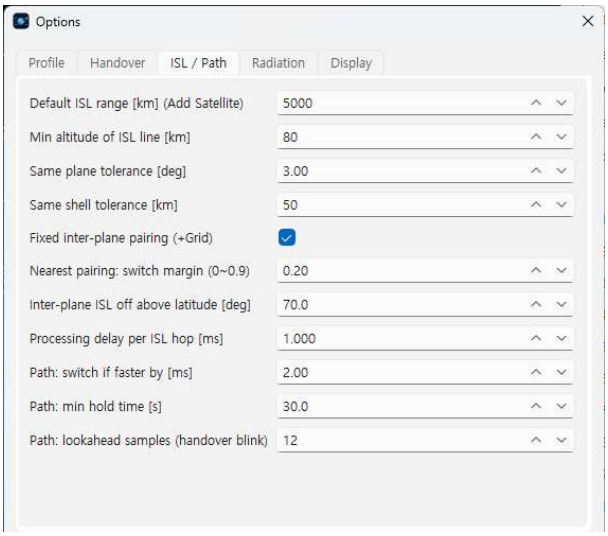


Figure 17. Options — ISL / Path tab

12. UDP Ethernet Output

Tools > UDP Output periodically sends the positions of all satellites and terminals, and optionally handover states and the ISL route, so that other equipment (e.g. the emulator control PC or a map display) can follow the simulation.

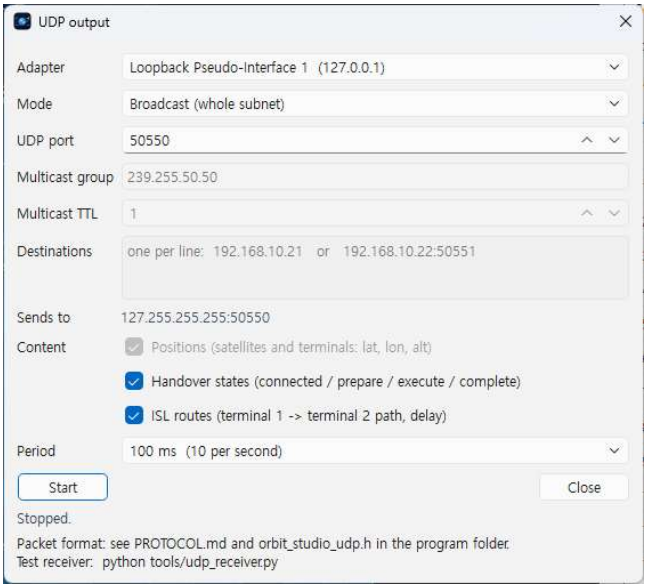


Figure 18. UDP Output dialog

Item	Description
Adapter	Network adapter (IPv4); the socket is bound to it
Mode	Broadcast (default) / Multicast (239.255.50.50, TTL) / Unicast (IP list, `IP` or `IP:port`)
UDP port	50550
Content	Positions (always) + Handover states + ISL routes
Period	100 – 1000 ms, 100 ms steps

Message	Content
Header (32 B)	magic "ORBS", version 2, msg_type, frame_seq, part index/count, sim_time (UTC s since 1970), record count/size, catalog_seq, flags
1 Catalog (40 B)	Type, kind, id, UTF-8 name — every 1 s and on change

Message	Content
2 Position (32 B)	Type, flags, id, WGS84 latitude, longitude, altitude [m] (float64)
3 Link (24 B)	Terminal, serving satellite, other satellite, state (NO_LINK, CONNECTED, HO_PREPARE, HO_EXECUTE, HO_COMPLETE), elevation, range, handover count
4 ISL route (variable)	Terminals A/B, satellite count, hops, delay [ms], length [km], route change count, list of all satellite ids

※ Little-endian, ≤ 1400 bytes per datagram. Allow the UDP port in the receiving PC's Windows Firewall. Details: `docs\PROTOCOL.md` and the C header `orbit_studio_udp.h`; test receiver: `tools/udp_receiver.py`.

13. Options, Saving and Files

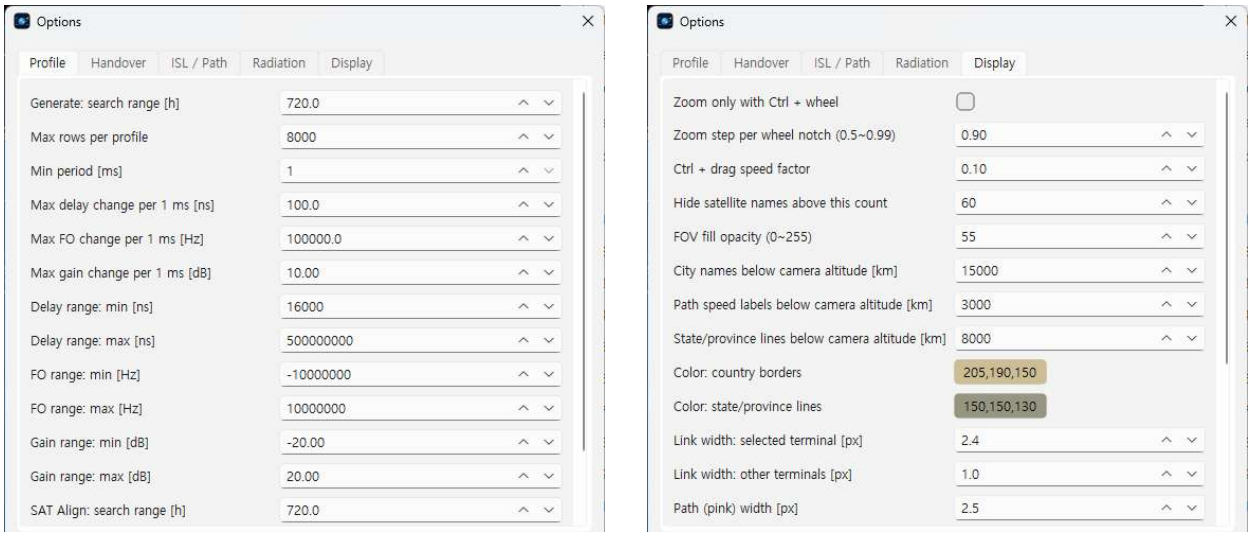


Figure 19. Options — Profile tab (emulator limits) and Display tab

Item	Description
Tools > Options (Ctrl+,)	Tabs: Profile (equipment limits, search range, analysis length), Handover, ISL / Path, Radiation, Display. Apply / OK / Cancel / Restore Defaults.
user_settings.json	In `%APPDATA%\MantisTech\Orbit Studio`. Only values that differ from the defaults are saved; delete the file to restore all defaults
Scenario file (.json)	File > Save / Save As / Open: satellites, terminals, profile parameters, time settings and view. Files of earlier revisions can be opened.
Window title	Shows the file name; * marks unsaved changes. Recent Files keeps 8 files.
net_settings.json	UDP output settings (same folder)

14. Technical Limitations and Accuracy

Profile accuracy is limited first by the knowledge of the satellite orbit, then by the simplifications of the propagation model, and finally by the time sampling and number resolution of the CSV file. The values below are typical estimates for engineering use; check one case against an independent tool (e.g. STK or GMAT) before critical tests.

14.1 Summary

Output	Resolution	Model error (orbit exact)	With TLE orbit (typical)
Delay	1 ns	< about 0.2 μs (light-time) + up to ~1.4 μs (UT1–UTC)	≈ 3.3 μs per km of range error; ~1 km at TLE epoch, growing 1–3 km per day

Output	Resolution	Model error (orbit exact)	With TLE orbit (typical)
FO	1 Hz	≤ 0.3 Hz numerical (550 km LEO, 2 GHz) + ~1 Hz relativistic terms at 2 GHz	≈ f/c × velocity error: ~7 Hz per 1 m/s at 2 GHz (scales with frequency)
Gain	0.01 dB	Relative free-space loss only (see 14.4)	≈ 0.016 dB per km at 550 km range — negligible
Timing	0.05 s (start/end search)	—	Along-track error appears as a time shift: ~0.13 s per km (LEO)

14.2 Orbit and time

Source	Cause and size	Effect / advice
TLE / SGP4	TLEs are mean elements fitted to tracking data; SGP4 error is typically about 1 km at the epoch and grows 1–3 km per day for LEO (larger during high solar activity or after manoeuvres).	Use a TLE with an epoch close to the test time (< 1–2 days). The shape of the profile is kept; mostly its timing and absolute delay shift.
Custom orbit	A TLE is built from the entered altitude with Kepler's law (mean motion). The propagated altitude can differ from the input by a few km.	Fine for generic scenarios; use a real TLE to reproduce a specific satellite.
GEO model	Fixed point, or two-body Keplerian 8-figure motion; Sun/Moon and Earth-oblateness perturbations and station keeping are not modelled.	For a real GEO satellite enter its TLE (SGP4 then reproduces the 8-figure).
Earth orientation	TEME → ECEF uses GMST rotation only from UTC; polar motion (~10 m) and UT1–UTC (≤ 0.9 s, up to ~0.4 km at the equator) are ignored.	Up to ~1.4 µs delay in the worst geometry; usually much less.
Terminal altitude	Altitude is above the WGS84 ellipsoid, not above mean sea level (geoid differs by up to ±100 m).	Up to ~0.3 µs delay; enter ellipsoidal height if known.

14.3 Propagation model

Not modelled	Typical size	Remarks
Light-time / Sagnac	Delay uses the instantaneous geometric range. Satellite motion during the 2–6 ms LEO travel time: up to ~0.15 µs; Sagnac for GEO: up to ~0.13 µs.	Relevant only for sub-µs timing tests
Ionosphere	Group delay $40.3 \cdot TEC/f^2$: at 2 GHz about 3–100 ns (higher at low elevation and solar maximum)	Decreases with $1/f^2$
Troposphere	About 8 ns at zenith, ~45 ns at 10° elevation; refraction raises the apparent elevation by ~0.1° at 10°	Service start/end may shift by a few seconds near the horizon
Relativistic frequency terms	Second-order Doppler and gravitational shift $\sim 10^{-9} \cdot f$: ~1–2 Hz at 2 GHz	—
Oscillator offsets	Satellite/terminal LO error and drift are not included	Add as a fixed FO in the emulator if needed

14.4 Gain model

The gain profile contains only the **relative free-space loss** $20 \cdot \log10(R_{min}/R)$. Antenna patterns (including beam roll-off toward the FOV edge), transmit power, atmospheric/rain attenuation, scintillation, polarisation loss and multipath are not included. Absolute link level is set on the emulator (fixed gain); multipath can be added with the SCE-C4202 Fading Channel mode. For a 550 km pass down to 10° elevation the gain range is about 10.4 dB, inside the ±20 dB range of the emulator.

14.5 Time sampling of the CSV file

The profile gives one value per period. How the SCE-C4202 moves between two rows (step or linear) is defined by the emulator; if values change in steps, the deviation from the true curve is up to one row's change. For the example of §8.6:

Period	Rows for the pass	Max delay step	Max FO step (2 GHz)
1000 ms	638	15.8 µs	159 Hz
100 ms	6,380	1.58 µs	15.9 Hz
80 ms	7,975	1.26 µs	12.7 Hz
10 ms	63,800 (> 8000)	158 ns	1.6 Hz

Recommendation: use the shortest period that keeps the pass within 8000 rows (≈ pass time ÷ 8000). For long passes split the pass into several profiles, or accept a longer period if the receiver under test tolerates the step size.

14.6 Scenario and function limits

- One-way link (satellite ↔ terminal) and one selected satellite per profile; handovers, ISL routes and feeder links are not written into profiles.
- Satellites are assumed to point at the Earth's centre (nadir); attitude manoeuvres are not modelled.
- Generate / SAT Align search 720 h (30 days); SAT Align treats a peak elevation ≥ 88° as overhead.
- A moving terminal whose speed changes instantly at a waypoint (smoothing and accel/decel = 0) produces a small FO step: f × Δv / c, e.g. 2 GHz and a 250 m/s reversal → ~3.3 kHz.
- Analysis: contacts shorter than the time step may be missed; at very high play speeds, handovers shorter than 1/31 of the look-ahead window may not blink on screen.
- TID: trapped particles only (AE8/AP8). Solar particle events, galactic cosmic rays and electron bremsstrahlung are not included; expect about a factor of 2 difference. Use IRENE (AE9/AP9) or SPENVIS for final design. SEE is not yet supported.
- Display: link lines are computed for (terminals × satellites) on every redraw; with hundreds of satellites and many terminals, playback may slow down.

15. Troubleshooting

Symptom	Check / action
`Map: built-in simplified map (no internet)`	Map data in the installation folder is missing or damaged. Reinstall Orbit Studio (settings are kept).
Generate finds no contact	Check FOV > 0, Service angle, that the satellite is selected, and that a pass exists within 720 h.
Warning: more than 8000 rows	Increase Profile period to the value given in the result dialog or split the pass.
SCE-C4202 shows E-1 in Samples	Wrong file for the item (e.g. FO file opened as Delay). Open `_delay` / `_fo` / `_gain` in the matching row.
Program does not start / is blocked	SmartScreen: More info → Run anyway; ask IT to allow `OrbitStudio.exe` in the antivirus.
UDP data not received	Receiving PC firewall (UDP 50550), correct adapter, same subnet for broadcast; use Unicast across routers or Wi-Fi.
Playback is slow	Lower `State/province lines below camera altitude` in Options > Display, turn off ISL links or reduce satellites.

16. Support and Contact

Item	Contents
Company	MantisTech (Mantis Technology Co., Ltd.)
E-mail / Web	mantis@mantistech.co.kr ｜ www.mantistech.co.kr
Related product	SCE-C4202 Satellite Channel Emulator (see the SCE-C4202 datasheet)
Third-party software	PySide6 (LGPL), numpy, sgp4, matplotlib, Natural Earth data — see THIRD_PARTY_NOTICES.txt

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