Testing Controlled Radiation Pattern Antennae (CRPA)

# Angle of Arrival Testing

- Controlled Reception Pattern Antenna (CRPA)

- Reduce effects of RF interference or determine arrival angle for authentication or sensing purposes

- Anti-Jam adaptive antenna (phased array)

- Antenna feeds manipulated in gain and phase to

  o Minimise jamming signals
  (Null Generation or Null Steering)

  o Maximise satellite signals
  (Beam Forming or Beam Steering)
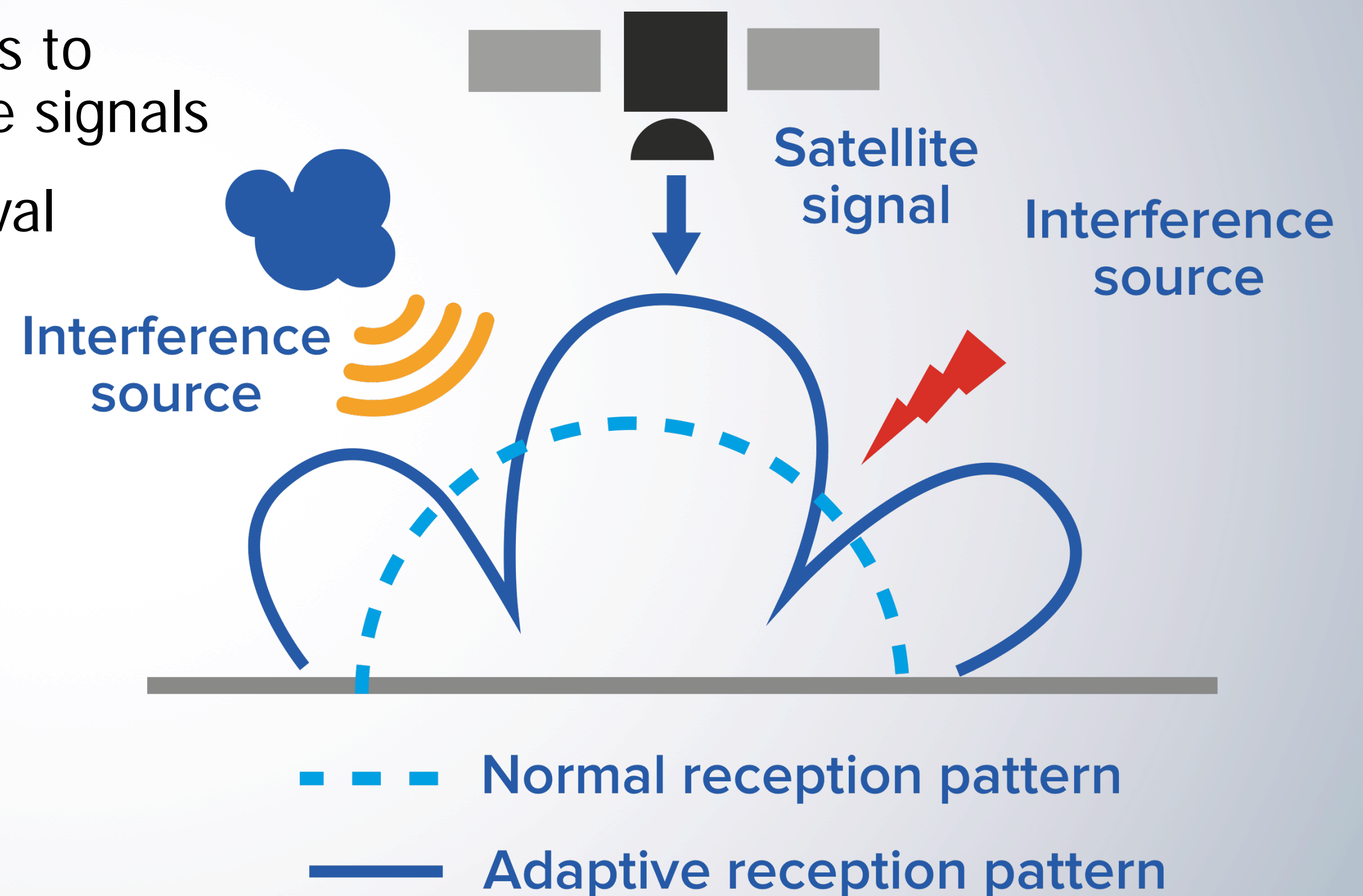
Military Anti-jam systems
Robust PNT for the Military

- Military users require accurate position for command and control as well as guidance

- During conflict, attempts will be made to jam the navigation systems of ships, aircraft, troops and unmanned systems from drones to cruise missiles.

- Controlled Reception Pattern Antenna (CRPA) can detect multiple mobile jammers and attenuate signals from the arrival vector of the jammer even when mounted on a fast jet being violently manoeuvred

- Testing with real signals involves expensive test flights and multiple jammers with the attendant costs, risk of interference with civilian GNSS users and vulnerability to detection

- The challenge that Spirent have met is to provide a range of affordable, flexible and discrete lab based test solutions

Interference source

Satrlite signal

Interference source

- - - Normal reception pattern
— Adaptive reception pattern
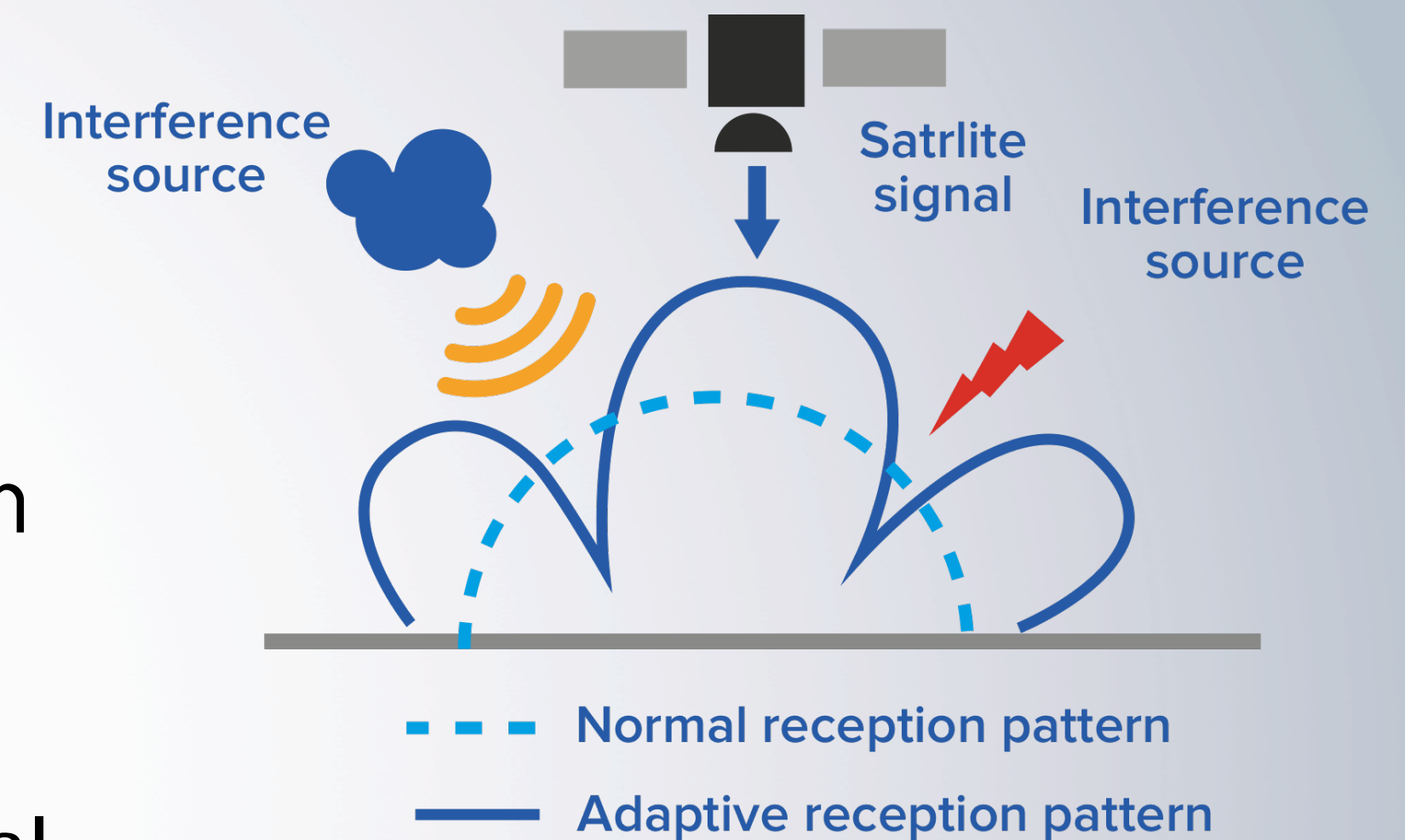
Controlled Reception Pattern Antenna

- CRPA systems use phased array techniques to reject interference signals or boost satellite signals

- Testing presents unique challenges as arrival vectors for wanted and unwanted signals need to be represented

- Spirent has extensive experience of conducted and radiated testing of CRPA systems

Satellite signal

Interference source

Interference source

- - - - Normal reception pattern

——— Adaptive reception pattern

Anti-Interference Testing

Jammer

GPS (OK)

Reception Antenna Gain

GPS (attenuated)

N

Key Test Choices

CRPA testing

Over The Air
- Outside test range — Jamming events and trials using real signals or inverted ranges — **Expensive, disruptive, lacks privacy**
- Indoor chamber — Simulated GNSS generated for each SV or arrival vector with real or simulated disruption

Preferred options

Conducted
- Multi-box — Composite signals for each antenna (including interference) generated independently and coherently
- Phase shift network — Signals for each SV generated, manipulated in phase and amplitude then combined for each antenna — **Expensive, complex**
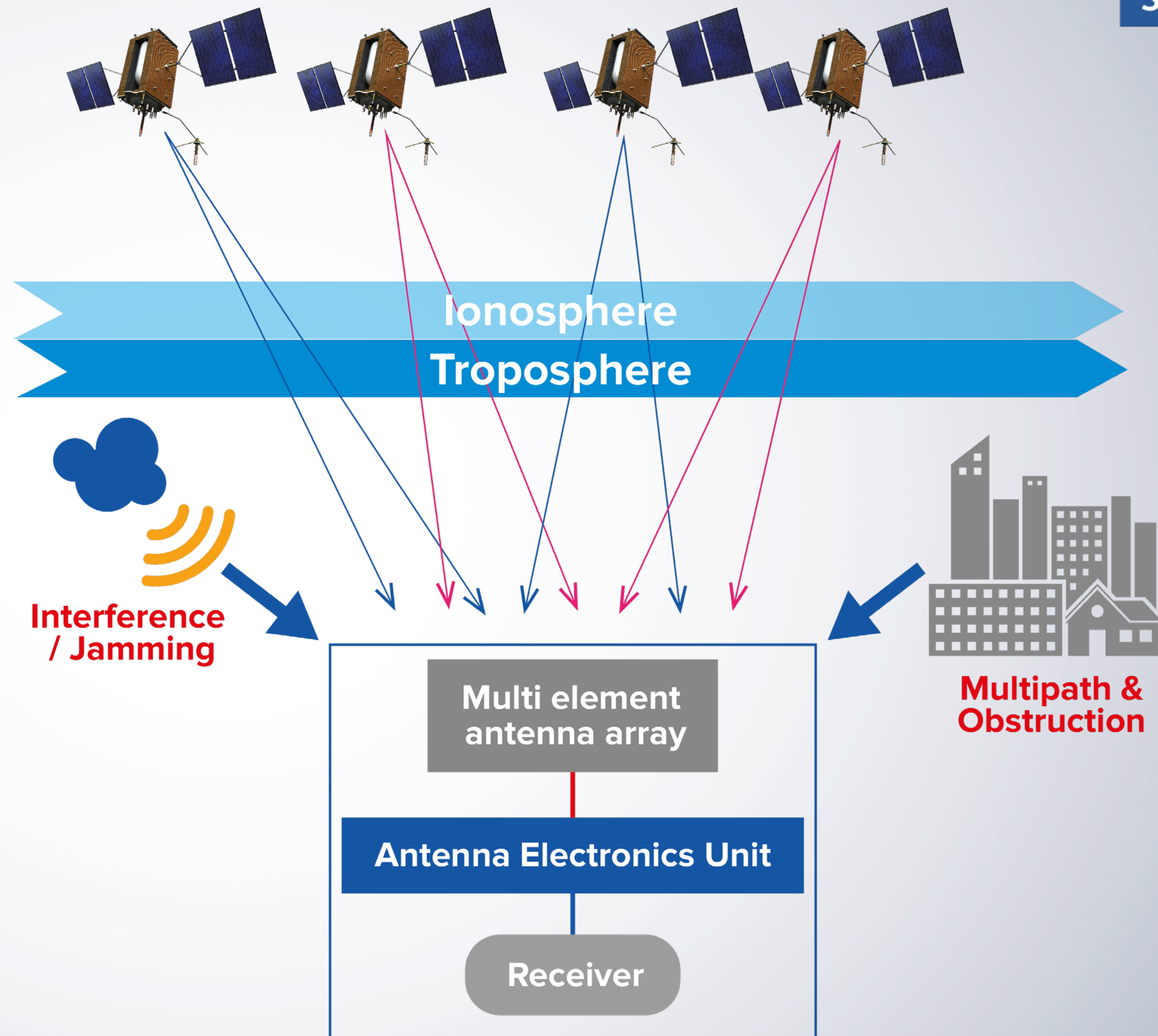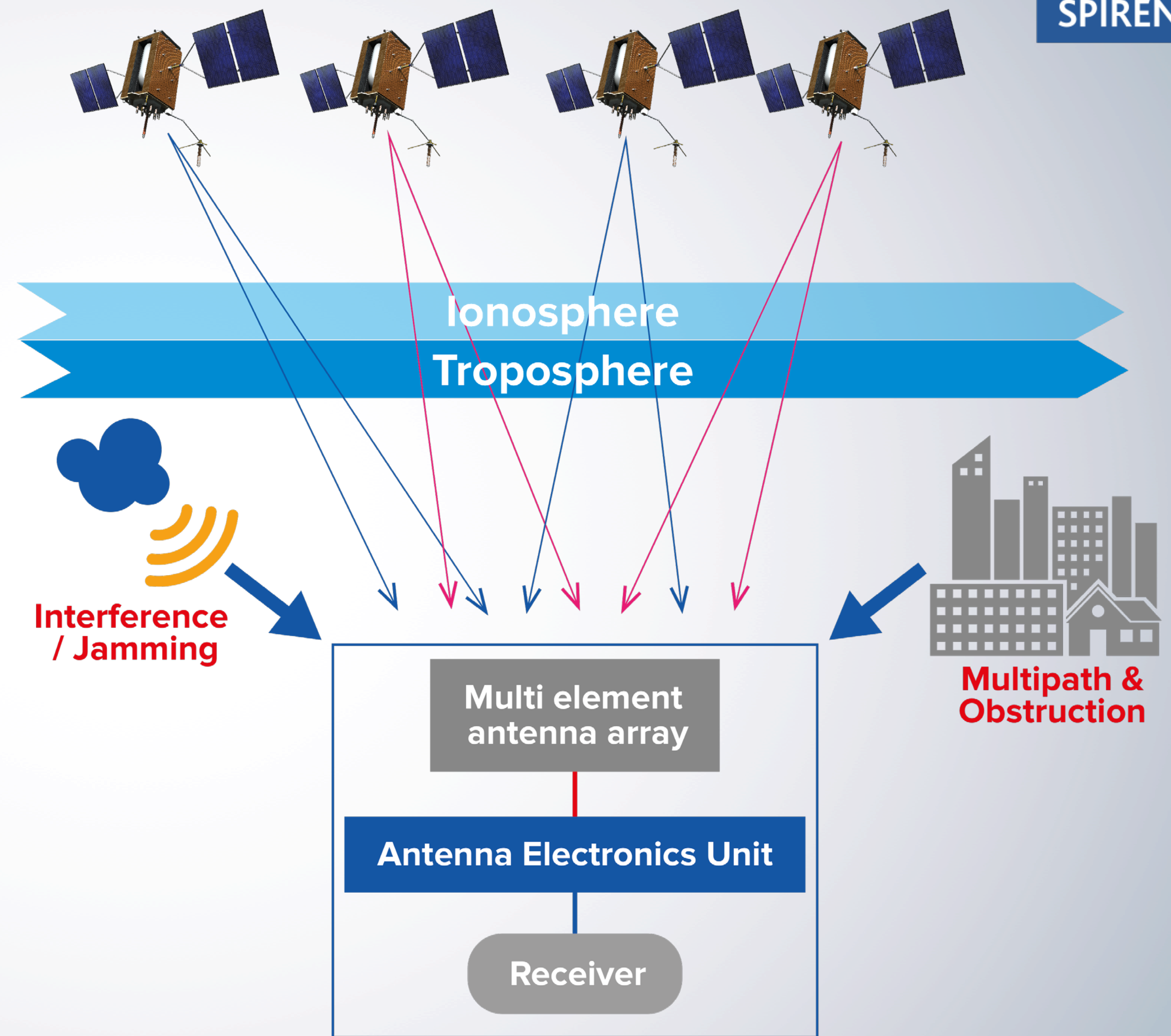
CRPA environment from a test perspective

- Each element from SVs to DUT and all in between needs to be represented

- Options centre on which elements are physically present and which are modelled and simulated

Ionosphere
Troposphere

Interference / Jamming

Multi element antenna array

Antenna Electronics Unit

Receiver

Multipath & Obstruction

Conducted Testing of CRPA

- For conducted testing a unique composite signal containing

- GNSS and interference is generated for each antenna element

- Carrier phase calibration allows arrival vectors to be accurately represented on a signal by signal basis

- The GNSS constellation, interference, environment and antenna elements are all simulated separately for each antenna element

Ionosphere
Troposphere

Interference / Jamming

Multipath & Obstruction

Multi element antenna array

Antenna Electronics Unit

Receiver

GSS9000 wave-front configuration (conducted test)

C50r SimGEN host

Each chassis can accommodate 10 banks
(can be a mix of GNSS and interference)

7 RF (one for each antenna
element) each containing
GPS L1, GPS L2 and
interferer (jammer) signals

**Control
distribution**

Each bank = up to
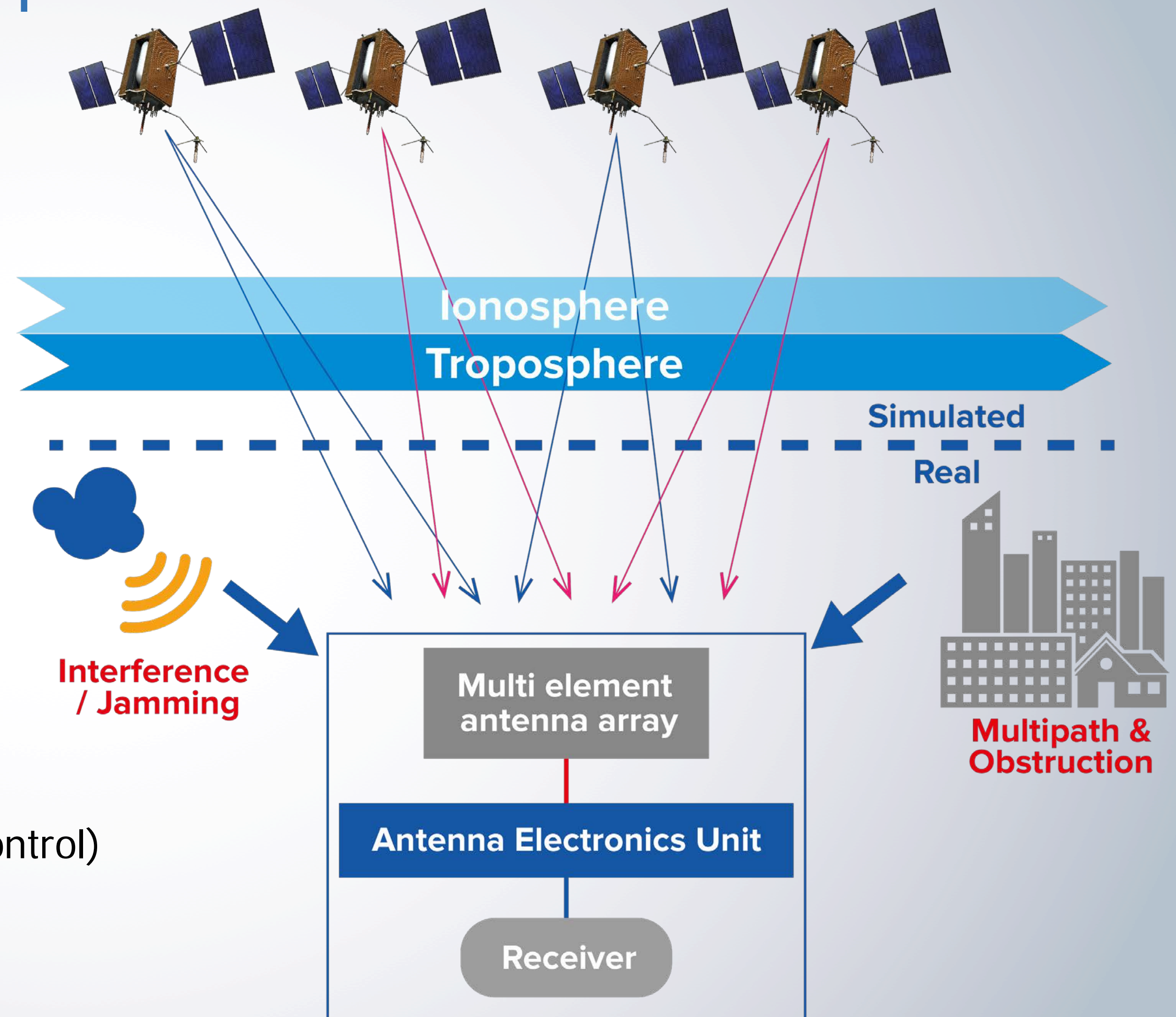16 channels of a single signal

Comments on simulator requirements for conducted testing

- One composite RF output is required per antenna element
  - Each composite output contains all GNSS signals and jammers with carrier phase of each component controlled to replicate the requisite arrival angles (wave-front simulation)

- Requires accurate and stable carrier phase alignment for both GNSS and jammer signals
  - Spirent employs a range of proprietary techniques to ensure unbeaten phase alignment and stability

Strengths	Challenges
Unlimited scenario duration and motion is supported Inertial aiding (emulated) can be supported	J/S limited to around 110dB by linearity (spurious) and uncorrelated noise on each instance of the jammer signal which will not be nulled by the AEU

OTA (Chamber) Testing Type - 1

- For radiated or OTA testing GNSS signals are broadcast into an anechoic chamber

- Each antenna fed from a signal generator output representing the signals from a single satellite

- Tx antenna locations represent SV locations which, if fixed, will mean short scenarios

- Jammers can be introduced separately into the chamber

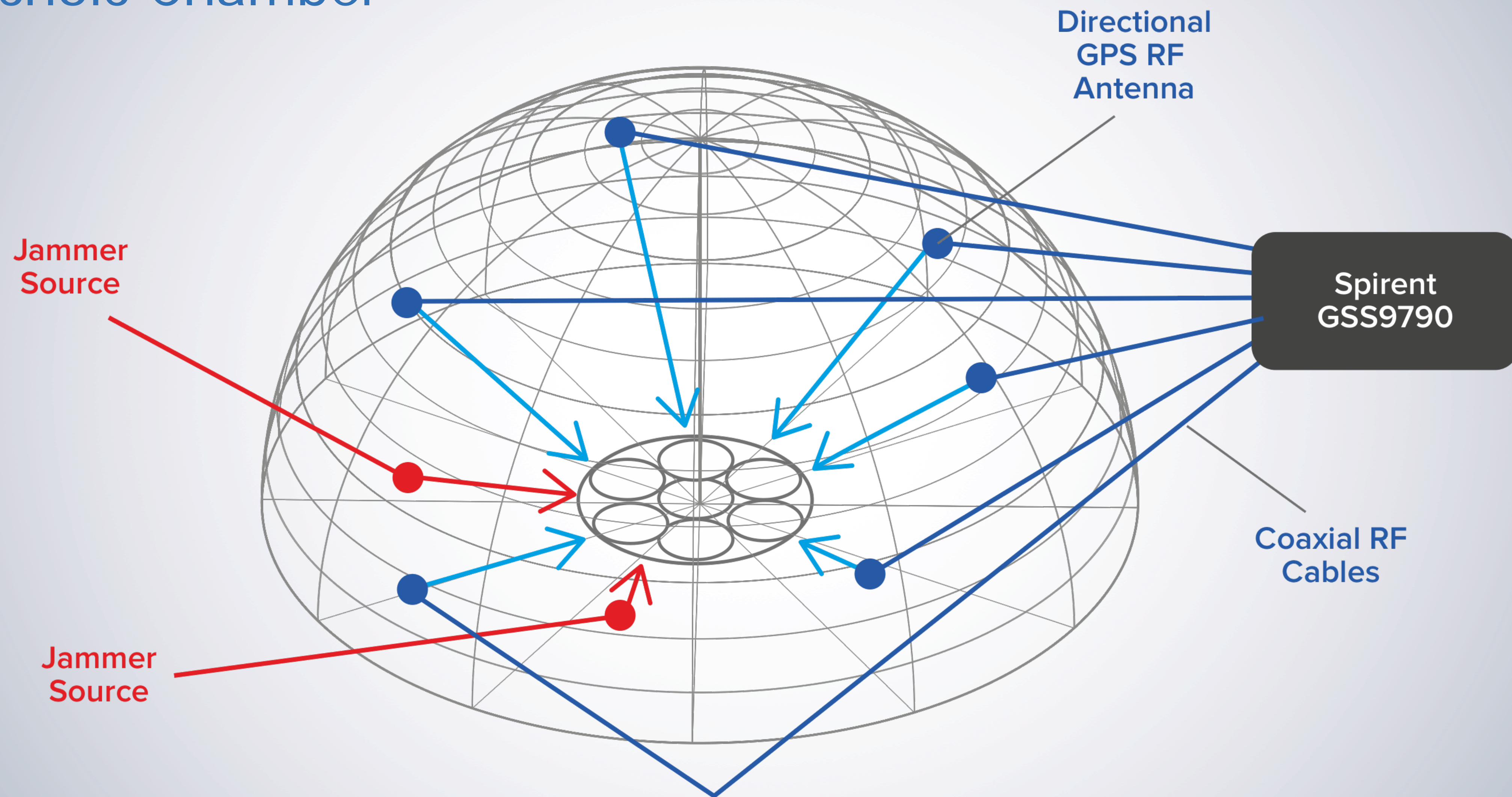 (optionally included in scenario and under software control)

Ionosphere
Troposphere

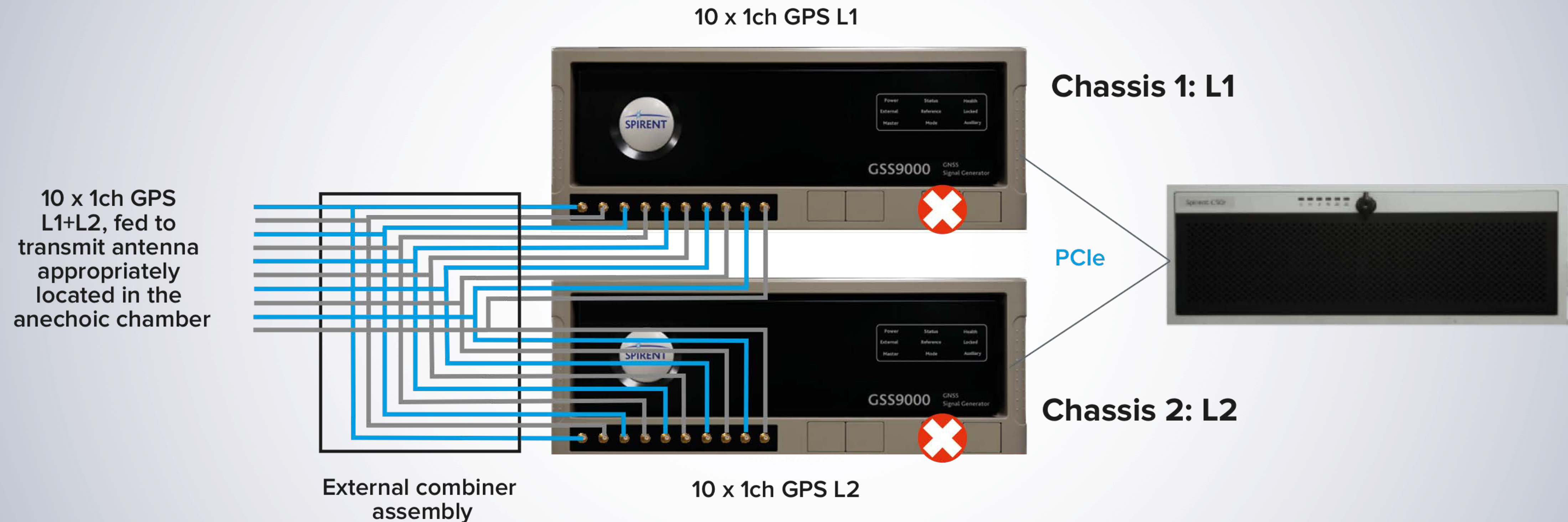Simulated
Real

Interference / Jamming

Multi element antenna array

Multipath & Obstruction

Antenna Electronics Unit

Receiver

OTA (Chamber) Testing Type - 1

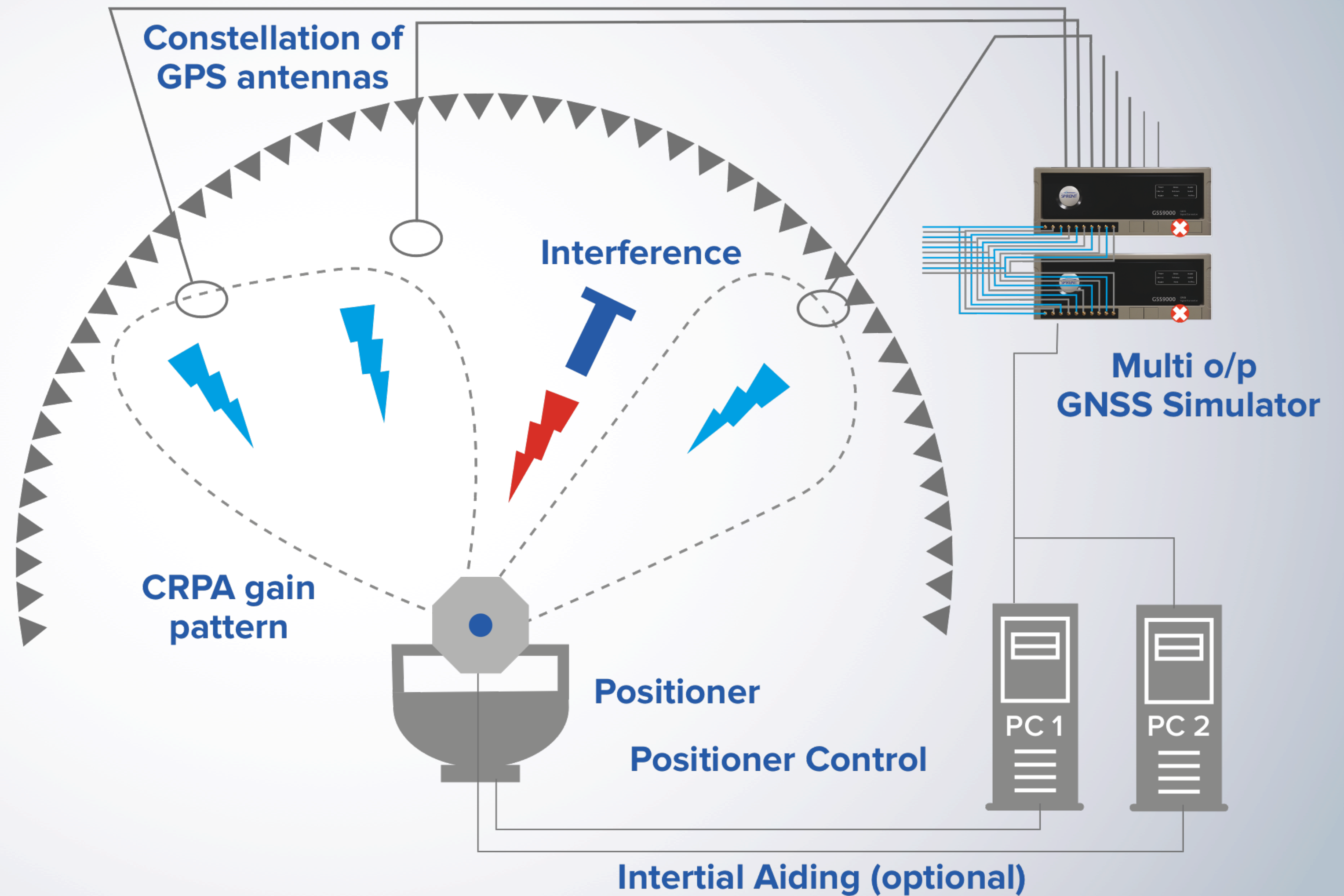Anechoic chamber example: DERA Boscombe Down UK

Example RFCS configuration supporting GPS L1L2 10 satellites in view
Additional constellation can be supported by adding chassis and antenna

Radiated testing in a chamber type-1.

Antennas are located to represent the azimuth and elevation of the satellites included in the scenario.

Position accuracy (ie angular error at the DUT) is normally acceptable for approximately 30 minutes.

Constellation of GPS antennas

Interference

CRPA gain pattern

Multi o/p GNSS Simulator

Positioner

Positioner Control

PC 1

PC 2

Intertial Aiding (optional)

SPIRENT

Comments on simulator requirements for radiated testing

- The receiver antenna is physically present in the test
  - The simulator requirements are independent of the number of DUT antenna elements
- One single channel RF output is required per SV represented in the scenario
- Each RF output contains only one Satellite signal and is hard-wired to an antenna appropriately placed in the chamber
- Strengths
- Unlimited number and power of jammers
- No carrier phase calibration required
- Challenges
- Large anechoic chamber needed
- Scenario duration and time and date limited by fixed placement of transmit antennas
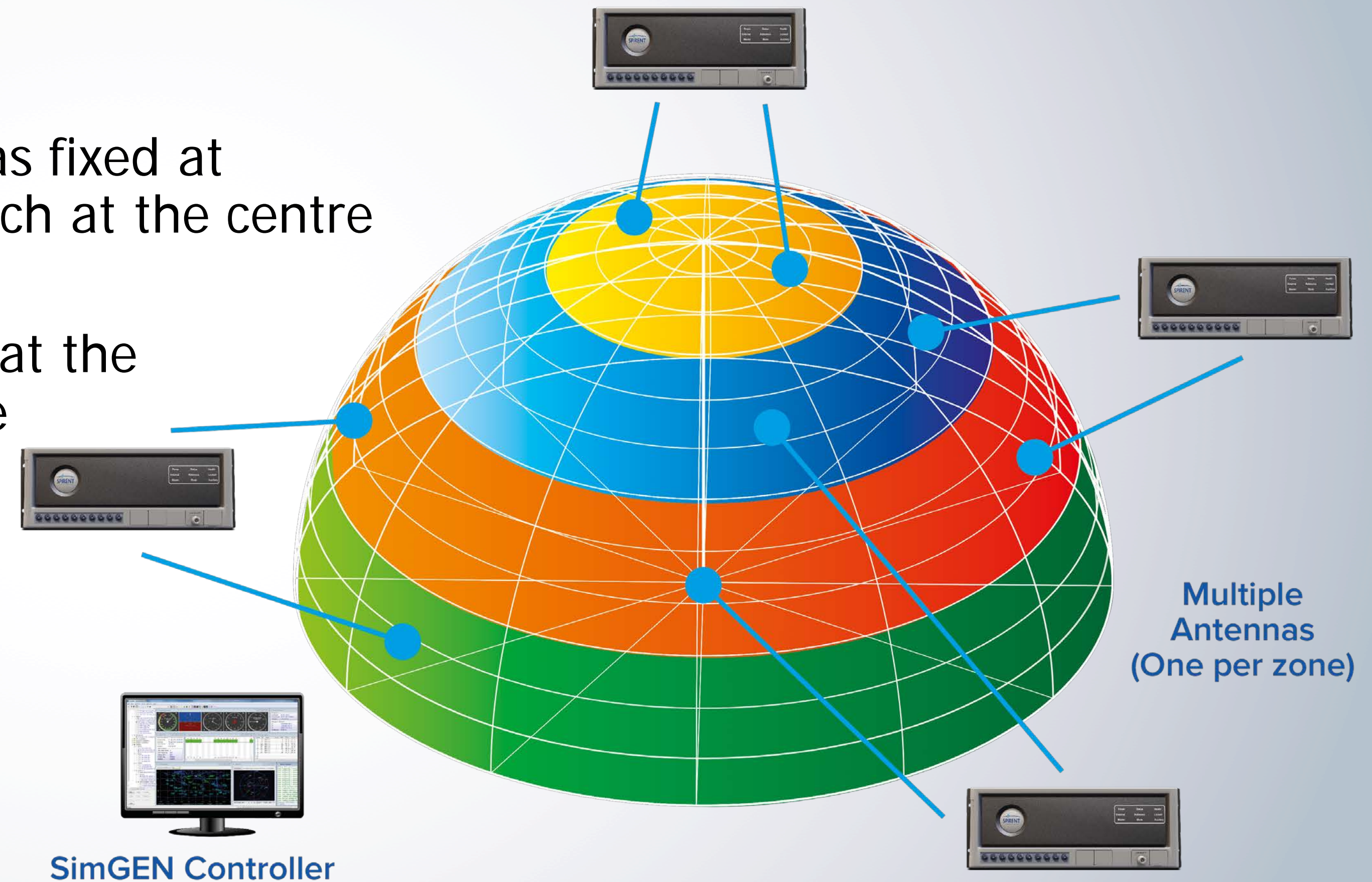
Comments on simulator requirements for radiated testing

- One single channel (multi-frequency) RF output is required per satellite in view
  - Each RF output contains a single satellite's GNSS signals.
    Carrier phase alignment is not required.

- Simulator requirements defined by constellations and signals and remain independent of DUT technology

- Jammers are represented by other RF sources introduced into the chamber
  - Flexibility of jammer types and power

Strengths	Challenges
Includes antenna array in the test Same RFCS requirements regardless of number of antenna elements Supports high J/S ratios from multiple jammer sources	Large chamber required. Fixed GNSS signal arrival vectors due to fixed antenna locations so angular fidelity is acceptable for only a few 10s of minutes with limited flexibility for changing date, time or location

OTA Testing Type – 2 aka "Zoned Chamber"

- A "zoned chamber" replaces Tx antennas fixed at SV locations with a grid of antennas, each at the centre of a tile or zone

- All SV within that zone are represented at the single antenna at the centre of the zone

- SV are handed of from zone to zone extending simulation time indefinitely

- Zone count trades off angular accuracy for frequency of zone transition

- More zones = better angular accuracy but more zone transitions (with phase discontinuity)

SimGEN Controller

Multiple Antennas (One per zone)

Comments on simulator requirements for zoned chamber

- The receiver antenna is physically present in the test
  - The simulator requirements are independent of the number of DUT antenna elements

- One multi-channel RF output is required per zone

- Each RF output contains signals from all the SV within the zone and is hard-wired to an antenna placed in the centre of the zone within the chamber

Strengths	Challenges
Unlimited time & date and scenario duration Angular error bounded by zone size (more zones = better angular accuracy)	Large anechoic chamber needed Zone transitions may disrupt receiver lock due to carrier phase discontinuity (fewer zones = less transitions)

GSS9000* based zone chamber implementation illustration

C50r multi-Sim host

Control distribution (multiple C50r each running SimGEN under the control of multi-sim
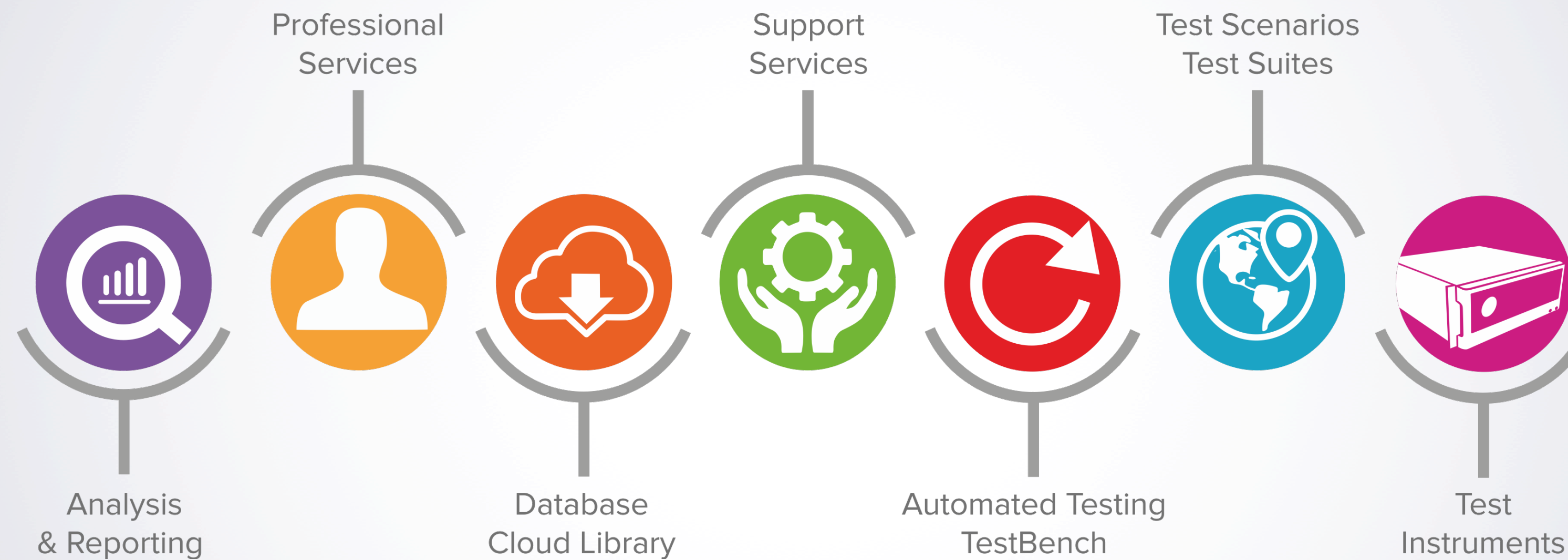
n Chassis where number of zones = nX2

e.g. 20 zones = 10 chassis

Each dual RF chassis drives two zones with multiple banks behind each RF output

* A similar architecture could be achieved using GSS7000 chassis

Summary of CRPA test approach trade-offs

Outside Test Range	Indoor Chamber	Conducted test - Multibox	Conducted Test – Phase shift
• Realistic situation • Expensive • Not private • Collateral interference	• Privacy secured • High J/S possible • Chamber infrastructure large and expensive • Type 1: Arrival vectors fixed by Tx antenna location • Type 2: Trade-off SV count, angular accuracy, scenario duration	• No chamber needed • Multi-Constellation • Separate antenna element test required • J/S limit of around 110dB • Hardware intensive	• Reduced number of chassis • Phase shifter expensive and complex

Professional
Services

Support
Services

Test Scenarios
Test Suites

Analysis
& Reporting

Database
Cloud Library

Automated Testing
TestBench

Test
Instruments

Spirent.com/positioning