



ALL.SPACE

DELIVERING
NETWORK
RESILIENCE WITH
INTELLIGENCE

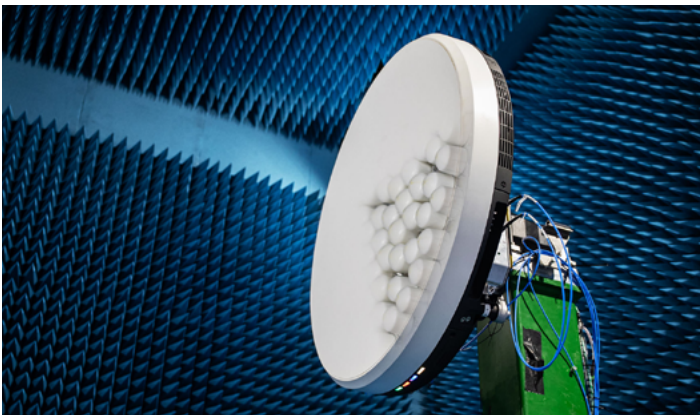
ADVANTAGES OF MULTI-LENS ARRAY TECHNOLOGY FOR SIMULTANEOUS MULTI-LINK, MULTI-ORBIT KA-BAND SATCOM IN DEFENSE APPLICATIONS

TECHNICAL BRIEF

Introduction

Modern defense and government operations increasingly rely on Ka-band satellite communications (SATCOM) to offer high-throughput, resilient links on mobile platforms. Among advanced antenna designs, ALL.SPACE's Hydra 2 lens-based array stands out, inspired by the Lycurgus cup, an ancient Roman artifact known for its optical filtering properties through nanoscale metallic inclusions. This inspiration led to the development of a novel lens-array beamforming technique that filters and guides electromagnetic energy via engineered dielectric lenses, enabling simultaneous high-gain, multi-beam connectivity with built-in interference rejection.

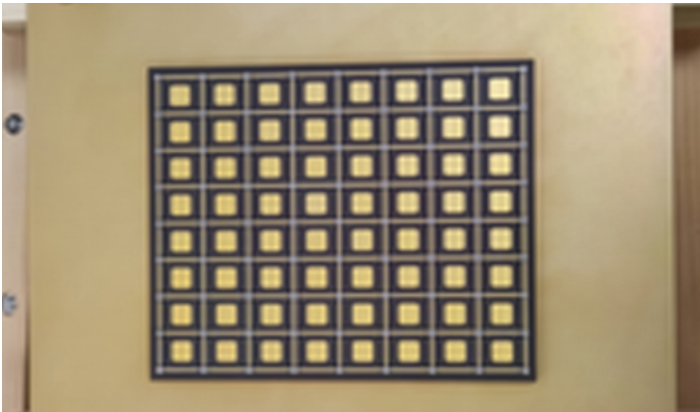
This brief compares four leading antenna architectures, based on key metrics relevant to mobile land and sea platforms:



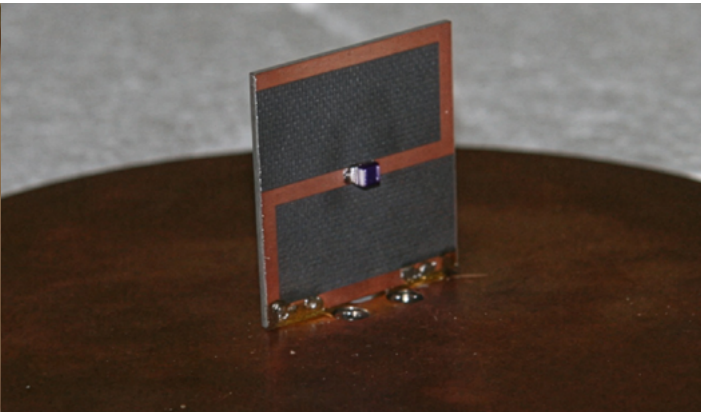
MULTI-LENS ARRAY SYSTEM



SINGLE LENS-BASED SYSTEM



TRADITIONAL PHASED ARRAY



METAMATERIAL ANTENNA

Antenna Architecture Overview

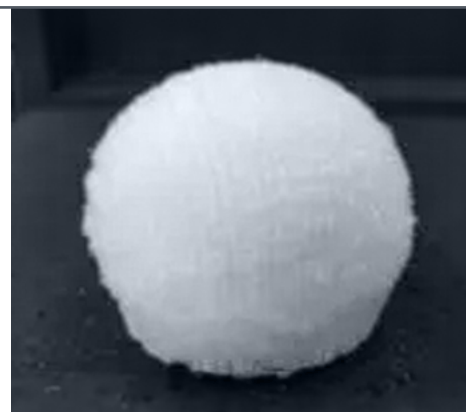
MULTI-LENS ARRAY SYSTEM

Multi-lens array antennas utilize dielectric lens elements to create highly directive beams. Each lens pairs with an independent feed that can be electronically switched to steer the beam without mechanical parts. This design allows simultaneous connections to satellites in different orbits (GEO, MEO, LEO) with high beam efficiency and minimal active components. ALL.SPACE's terminal technology is built on transformational optics and digital beamforming, employing multiple transmit and receive lenses on top of an array.



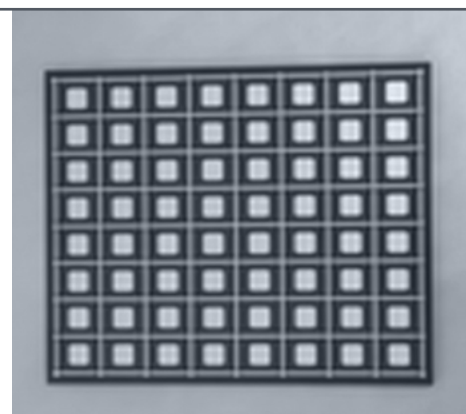
SINGLE LENS-BASED SYSTEM

Includes Luneburg and Rotman lenses. Luneburg lenses are spherical, gradient-index dielectric structures that provide high gain and wide-angle scanning by moving the feed. Rotman lenses are flat beamformers used with arrays to produce multiple beams in fixed directions. These systems are passive and affordable but often require mechanical motion or switching. The main challenge for Luneburg lenses, however, is that they must be spherical, which can make them very large in diameter and height to achieve a reasonable aperture size and performance. This makes them comparable to traditional parabolics in size and shape, but significantly heavier.



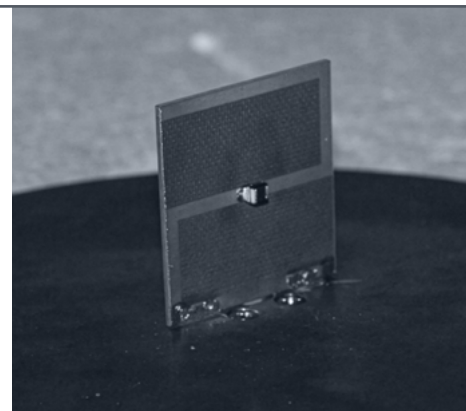
TRADITIONAL PHASED ARRAY

Composed of many electronically controlled radiating elements, phased arrays steer beams through dynamic phase shifting of each element. They allow ultra-fast electronic steering and adaptive interference mitigation. Despite their capabilities, they require high power, complex thermal management, and often large numbers of expensive microchips to operate the array.



METAMATERIAL ANTENNA

Use reconfigurable metasurfaces with tunable elements to produce steerable beams controlled by software. These antennas feature low power consumption, slim profiles, and the potential for multi-band operation. While they have less beam agility and gain compared to active arrays, they provide beneficial SWaP characteristics. Because RF signals must often be centrally distributed, typically through a parallel-plate waveguide, it becomes nearly impossible to distribute multiple independent signals without interference or very wide frequency separation. As a result, multi-beam operation is very challenging with this technology.



Technical Comparison

Metric	Multi-Lens Array (Hydra 2)	Single Lens System	Traditional Phased Array	Metamaterial ESA
Beam Steering	Electronic feed switching	Feed movement or port switch	Full electronic steering	Software-tuned metasurface
Beam Agility	Fast, sub-ms switching	Moderate (mechanical limits)	Fast, sub-ms switching	Fast, ms-level switching
Elevation Scanning Range	±70°, maintaining performance at scan	Hemispherical (Luneburg)	±60°, extendable with panels	±60°, extendable with tiling
Gain Efficiency	Moderate-High (40–70%)	High (up to 80%)	High (60–70%)	Moderate (~35–50%)
Multi-Beam Support	Native, two concurrent beams (scalable)	Limited	Possible, complex & costly (requires duplication)	Limited per band (or under development)
Interference Mitigation	Spatial filtering via lenses	Narrow beam, no adaptivity	Adaptive nulling, tapering	Beam shaping only
Size & Weight	Compact, modular design	Varies, often bulky	Moderate (Heavy due to heat dissipation)	Moderate, thin panels
Power Consumption	Moderate (minimal electronics)	Very low	High (many active elements)	Low (passive surface)
Cost Profile	Medium, cost-effective per beam	Medium	High	Low-Medium

Advantages of Multi-Lens Array Systems

TRUE MULTI-LINK, MULTI-ORBIT CAPABILITY

The ALL.SPACE Hydra 2 terminal represents the most advanced version of this architecture. It supports two independent beamforming systems, each creating its own electronically steerable beam. This allows true multi-link, multi-orbit operation from a single platform, supporting simultaneous connections to separate Ka-band satellites across any orbital regimes. By combining these features into one terminal, Hydra 2 reduces the need for multiple systems, lowering Size, Weight, Power, and Cost (SWaP-C) while enhancing operational flexibility. Its software-controlled beam steering enables quick redirection with high angular accuracy, which is crucial for dynamic and mobile platforms.

INTERFERENCE REJECTION AND ANTI-JAM RESILIENCE

Hydra 2's lens-array beamforming offers superior protection against unintentional and intentional interference. The high-gain lenses function as spatial filters, naturally blocking signals that are not aligned with the target satellite. This spatial filtering redirects off-axis interference to inactive feeds, shielding sensitive front-end electronics from damaging energy. Unlike traditional phased arrays, where omnidirectional element patterns allow interference to reach every amplifier, the Hydra 2 architecture minimizes exposure and maintains terminal performance even in dense electromagnetic environments.

BEAM ISOLATION AND REDUNDANCY FOR MISSION CONTINUITY

A key advantage of the Hydra 2 system is its beam-level isolation. **Each terminal's two beams operate with separate RF chains and front-end electronics.** This guarantees that the other beam remains fully operational and at full performance, even if one is compromised by saturation, interference, or environmental factors. Unlike phased arrays, which often share beamforming electronics and create single points of failure, Hydra 2 enables operators to maintain a vital full-performance connection to a second satellite, even if it's in a different orbit. This ensures reliable communication in contested or degraded conditions.

SUPERIOR SCAN PERFORMANCE AND CONSISTENT LINK BUDGETS

A unique advantage of the Hydra 2's multi-lens array architecture is its ability to maintain nearly flat performance across wide scan angles. Unlike traditional phased arrays and metamaterial systems, which often suffer sharp drops in transmit EIRP and receive G/T once beams are steered beyond $\sim 60^\circ$ off-boresight, Hydra 2 sustains high efficiency out to $\pm 70^\circ$. This ensures that even at extreme scan positions, operators retain full-performance link budgets without the degradation that typically compromises throughput and resilience in other architectures. By delivering consistent Tx and Rx performance across its full scan range, Hydra 2 maximizes operational flexibility for mobile users who cannot always align close to boresight, whether maneuvering on rugged terrain, through obstructed urban landscapes, or under dynamic sea states.

BUILT FOR RESILIENT, MOBILE OPERATIONS

Hydra 2's architecture is designed for reliable defense-grade performance in mobile and high-threat environments. Its lens-based design reduces power use, removes complex active parts, and provides directional accuracy without moving components. This makes it suitable for ground vehicles and ships that need steady, resilient connectivity across multiple SATCOM networks.

Advantages of Multi-Lens Array Systems

In summary, Hydra 2's multi-lens array design offers unmatched multi-link, multi-orbit capabilities, built-in anti-jam protection, and mission-critical redundancy, all in a compact, rugged package designed for modern defense operations.

Use Case Alignment



GROUND MOBILE

Hydra 2 is highly optimized for resilient communications on the move. Two simultaneous Ka-band beams provide uninterrupted connectivity across multiple orbits, making it ideal for tactical vehicles and mobile command posts.



NAVAL PLATFORMS

Hydra 2's multi-beam capability enhances satellite diversity and redundancy, decreasing blockage risk and ensuring seamless failover at sea.



QUICK DEPLOY AND FIXED / COMMS-ON-THE-PAUSE:

Hydra 2 enables rapid setup and reliable connectivity for mobile shelters, forward operating bases, or pop-up command posts that require simultaneous GEO and MEO satellite access while stationary.



Summary

The ALL.SPACE Hydra 2 lens array terminal is the most capable solution for achieving true multi-link, multi-orbit SATCOM resilience in mobile defense applications. Unlike conventional antennas, Hydra 2 combines multiple independent lens modules, each able to form a high-gain, electronically steered beam. This allows simultaneous satellite connectivity across GEO, MEO, and LEO constellations from a single terminal, ensuring uninterrupted communications through active failover, load balancing, and orbital diversity.

Its passive frontend lens-array beamforming architecture delivers superior spatial filtering by automatically rejecting off-axis interference and blocking jamming energy from reaching sensitive front-end components. Each beam path stays isolated, so interference or saturation on one link does not impact others, ensuring unmatched operational continuity. Paired with a compact, rugged design and moderate power use, Hydra 2 provides defense users with a next-generation, MIL-STD-qualified terminal built for mission-critical communications in contested, congested, and dynamic environments.

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