New Concepts for CUBESATs and Hybrid Networks applications

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SUMMARY

CHARACTERISTICS OF DISTRIBUTED SYSTEMS IN THE SPACE DOMAIN

A distributed system has many interesting prerogatives:

- Allows for increased communications and throughput in covered areas;
- Provides inherent redundancy, so individual satellites can be implemented more easily;
- Service availability is increased especially when operating in high orbits.

The system can have different functions but also specialization within the system itself through sub-groupings. Specialization can extend to command and control of the system by integrating ground station functions with communication relays (ISLs) or even providing mission control services from one of the platforms in orbit.

DISTRIBUTED SYSTEMS BASED ON FORMATIONS OF MICROSATELLITES

A revolutionary distributed space system fields a group of coupled and highly autonomous satellites that provide in-orbit flexibility, redundancy, reconfigurability and gradual degradation, peculiar technological elements are:

- On-board satellite tracking of relative and absolute positions and attitude ;
- Navigation of satellites in formation;
- Maneuvering, configuration for functionality, collision avoidance, and formation configuration optimization
- Modeling of orbital mechanics and impact of differential drag and solar disturbances
- Fleet and individual satellite autonomy against mission objectives , including failure detection, reconfiguration and graceful degradation
- Capability of operations planning and intra formation synchronization
- Decentralized control and computation for a fleet of many (even hundreds) vehicles

DEFENSE APPLICATIONS: LOW FREQUENCY

Huge bandwidth is not always mandatory for communications-in fact, in many applications, short, encrypted messages are preferred. Low latency and timeliness are the keys to success!

Examples are:

- Communications with mobile vehicles means particularly aircraft but also submarines.
- Push-to-talk messaging, also currently in vogue at US Army
- S&R for recovery in situations where an incident has occurred
- IoT messaging to retrieve information from remote terminals even deployed in inaccessible territory
- Operational commands to be sent to deployed departments and unmanned vehicles.
- Ubiquitous emergency signals including civilian ones.

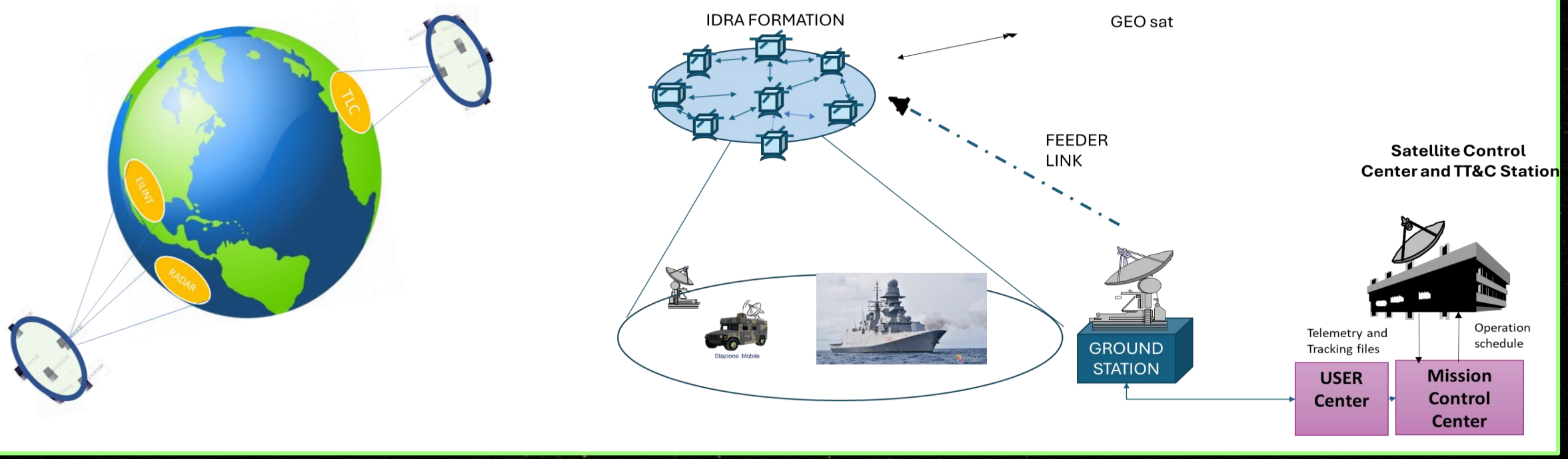
DEFENSE APPLICATIONS: LOW FREQUENCY

Low frequency, narrow band and high power communication systems are difficult to jam. Low frequency bands are little affected by weather conditions and therefore highly secure and available. Unfortunately, low frequencies require large antennas especially from space in order to focus the radiation pattern. These antennas are difficult to embark on satellites albeit large ones.

Then the possibility of using cooperating satellites in close formation in a distributed array overcomes the limitation imposed by both the capabilities of the individual satellite and that of the reduced gain of individual antennas. In conclusion, VHF/UHF communications provides a credible and feasible option for global communications at an affordable cost but needs one more technological step.

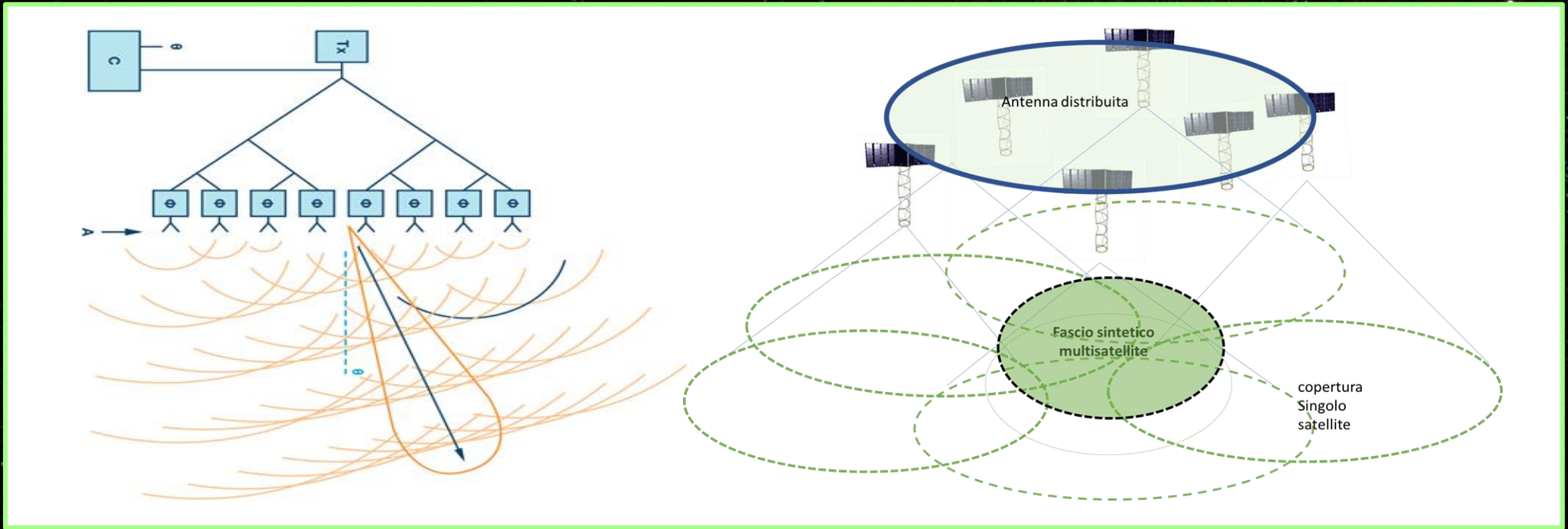
IDRA: IntegrateD multifunctional satellite sRrAy)

Satellites in close formation with distributed and synergistic payloads can provide innovative approaches in applications or as in the case of IDRA for the realization of a large scattered/distributed antenna to improve performance characteristics of otherwise unfeasible systems



IDRA: SPACE DISTRIBUTED ARRAY

Distributed arrays have opening widths equal to regular/filled/complete arrays but are sparsely populated. They consist of vacancies that occur due to missing/inactive sensors. Vacancies are deliberately created and are woven into the sparse array design to achieve certain desired features. IDRA will realize a distributed array in flight.



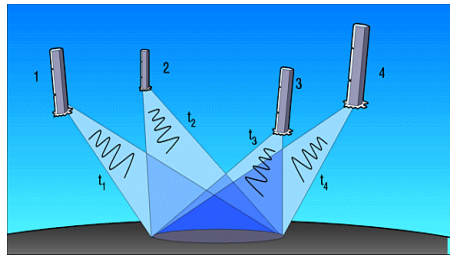
IDRA: SYSTEM OPERATIONS

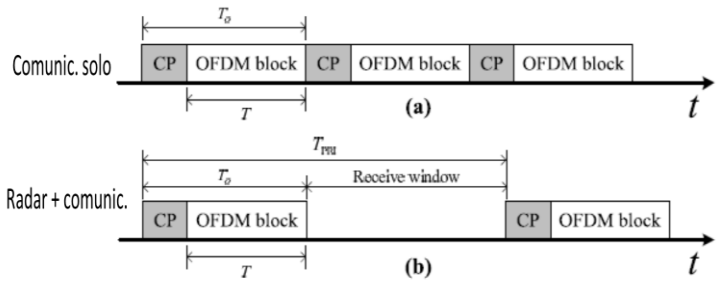
IDRA is a versatile system equipped with a programmable SDR payload. This makes it possible to optimize mission territory operations (e.g. frequencies, power, etc.), in detail:

- Based on the entire sparse array configuration by placing satellites in relative positions appropriate.
- In operating modes: communications, jammer, radar, navigation positioning, ELINT.In access protocols (typically TDMA with the possibility of operating TDD, HFDD or FDD).
- In waveforms (modulations, frequency, codes, encryption).
- In the Power transmitted. (also to be able to counteract a disturbance or comply with ITU requirements)In the beam directivity in combination with the other payloads of the sparse satellite array.
- The number of satellites in formation (to be studied in detail) and their geometric configuration.

IDRA: FURTHER HYBRID EVOLUTION

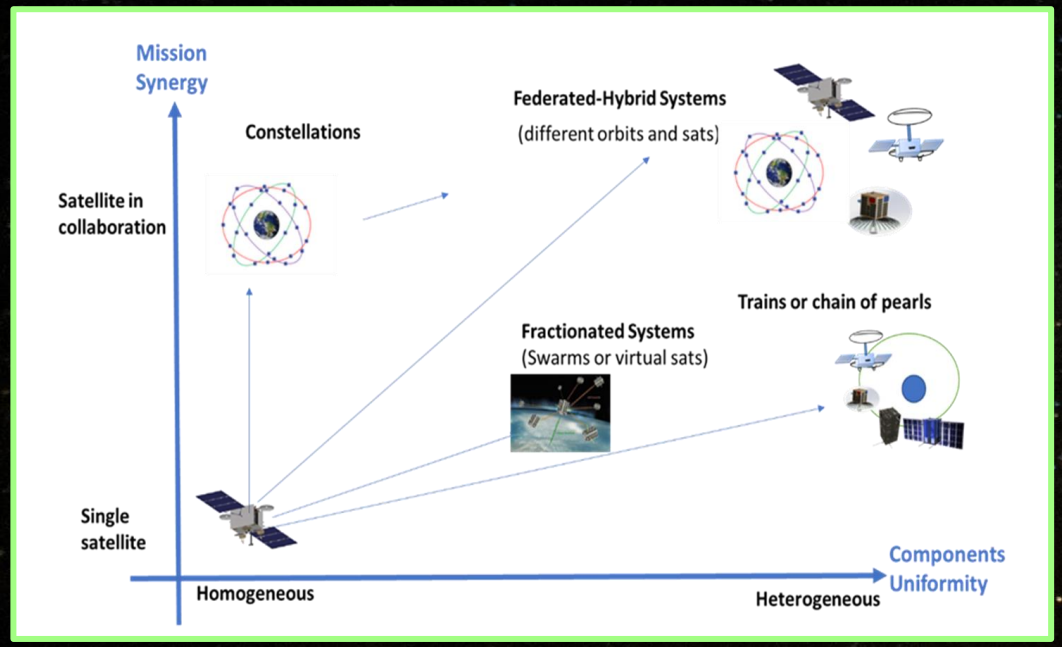
The goal is to integrate communication and radar functions into a single system. It is noted that this radar/communication integration is also envisioned for 6G and represents the natural evolution and convergence of electronic systems.





HYBRID SYSTEMS

"Homogeneous" satellite systems may not always be able to support communications independently, particularly in crowded or contested environments. Therefore, it is important to diversify satellite networks and establish connections between terrestrial and airborne systems. In this context, the PHORCYS project is proposed for high-safety value applications, aiming to connect and enable communication between heterogeneous systems in water, air, and space.

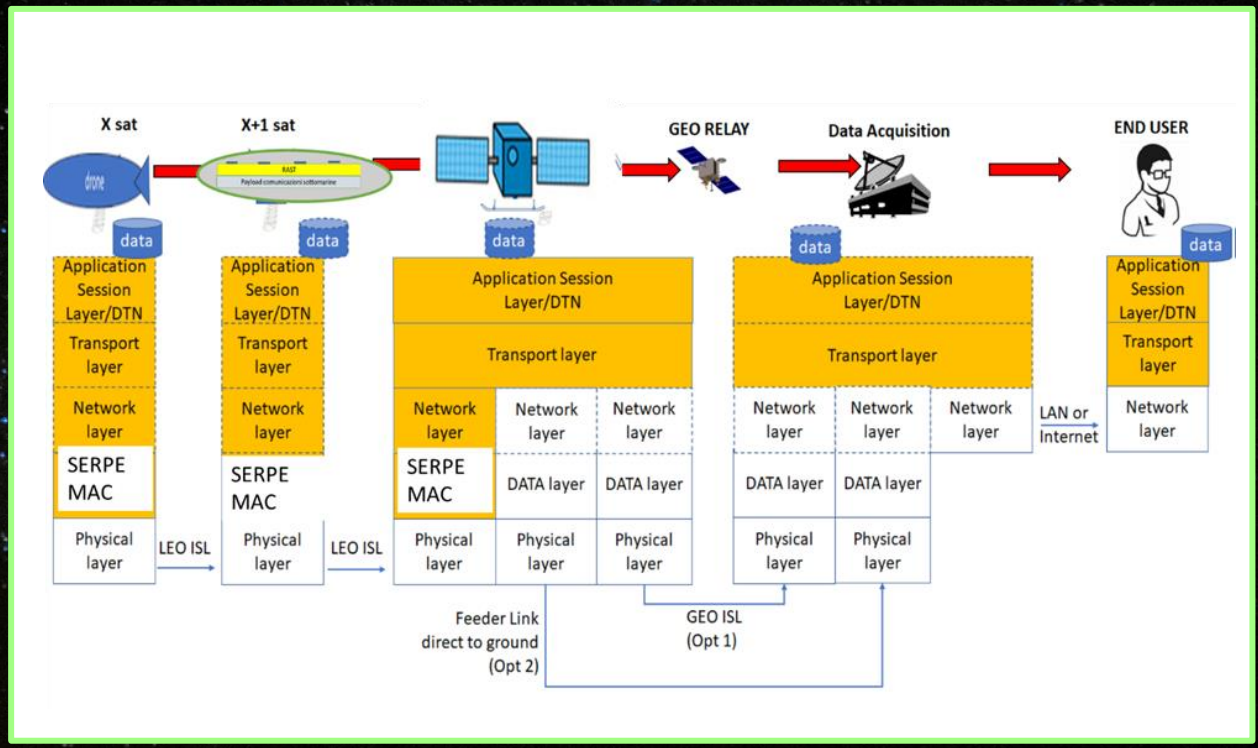


"The most effective and highest performing networks will dynamically integrate transmission via multiple orbits, multiple frequency bands, and integration with terrestrial, avionic, marine and submarine components, such as wired or wireless for defense crafts and infrastructure applications."

PHORCYS: adaPtive Hybrid telecOmmunications for integRated spaCe-submarine sYstem applicationS

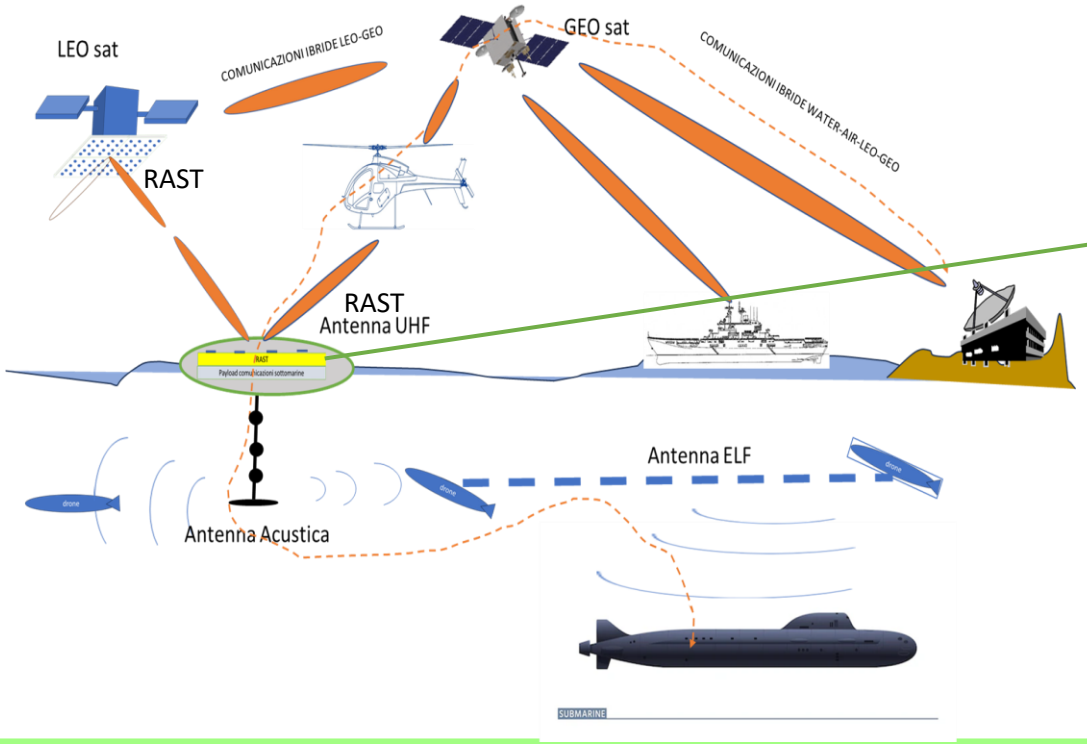
PHORCYS is a hybrid and multihopping communication system that allows to connect ships, submarines, UMVs and BOEs to satellites and air vehicles through some characterizing elements:

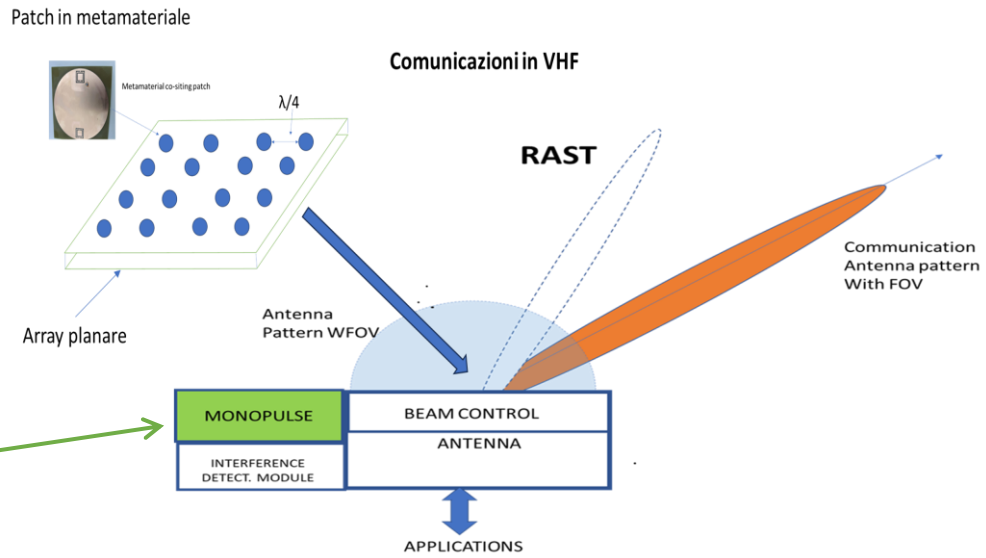
- An innovative retrodirective antenna in the UHF band (RAST-Retrodirective Antenna for Space Telecommunications) is combined with an SDR modem. The antenna can be installed on marine systems, air and space vehicles, and has flexibility, versatility, and resistance to interference.
- In the Phorcys system, the RAST antenna is connected to an underwater communications payload.-
- An innovative inter-satellite communication protocol suitable for hybrid space systems with multi-hopping capabilities is also part of the system.



PHORCYS: SYSTEM ARCHITECTURE

To create an antenna equipped with beamforming, one approach is to use retrodirective technology. A retrodirective antenna retransmits the received signal back in the same direction from which it arrived. Additionally, the retransmitted signal is phase-locked with the received signal, making deception and interference more difficult.





This also reduces the need to lock the incoming frequency with its Doppler at each burst. While it's feasible to create relatively small antennas with beam steering and nulling capabilities at high frequencies (> S band) using radiator arrays. It's much more challenging at lower frequencies, such as in the UHF band (< L band) due to the larger size of the elements (radians = λ/2). The concept of creating a UHF array involves using metamaterial technologies to reduce the size of the radiators. These smaller radiators are then placed at intervals of λ/4, allowing for better control of the antenna pattern within the same surface dimensions..

CONCLUSIONS

IDRA and Phorcys are two cutting-edge projects that embrace current technological trends. They aim to create highly performing systems by combining different sectors or application domains to provide ubiquitous services even in dual environments through synergy and convergence.

NPC has built a robust team with significant scientific expertise to drive its system development forward.
The development has recently started and it is expected to progress rapidly in the upcoming months."

Space is more a more becoming a key environment to better develop economic and security activities on the Earth however it is a limited resource and competition is ongoing.

BUT.....

“Victory will smile upon those who anticipate changes in characters of “business”, not upon those who wait to adapt themselves after changes occur.”

THANK YOU FOR YOUR ATTENTION

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