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The role of the Italian Space Agency in investigating high frequencies for satellite communications: The Alphasat experiment

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Summary
Since the 1970s, satellite communications have been continuously evolving and improving to provide services characterized by increasing complexity and quality. This evolution has been supported by the constant increase in the operating frequency for achieving the necessary high data rates. This contribution focuses on the long-term key role of the Italian Space Agency in supporting research activities on (and the developments of) high-frequency satellite communication systems. The Alphasat experiment is the most recent effort of the Italian Space Agency, in collaboration with the European Space Agency, to thoroughly investigate the severe detrimental atmospheric effects impairing radio waves at high frequency (specifically, Ka and Q bands) and the associated fade mitigation techniques (eg, uplink power control, site diversity, and adaptive coding and modulation) required to achieve the typical target quality and availability of modern satellite communication systems.

KEYWORDS
Alphasat experiment, atmospheric propagation, fade mitigation techniques, satellite communications

1 | RESEARCH ON HIGH-FREQUENCY SATELLITE COMMUNICATIONS: THE LONG HISTORY OF THE ITALIAN SPACE AGENCY

The Italian Space Agency (ASI) is a public entity under the supervision of the Italian Ministry of Research and Universities. The ASI was founded in 1988. Its purpose is to coordinate all Italian efforts and investments in the space sector that started in the 1960s.

In 20 years, ASI became one of the most significant players in the world in space science, satellite technologies, and in the development of mobile systems for exploring the universe. Today, ASI has a key role at European level, where Italy is the third contributor country to the European Space Agency (ESA) and to the development of European Union Space Infrastructure projects, European Geostationary Navigation Overlay Service, Galileo, and Global Monitoring for Environment and Security. The European activities of ASI include both participation in ongoing EU research projects and provision of H2020 national representatives and delegates in ESA programs.

The agency role is to enable the implementation of space programs and infrastructures, supporting the institutions and allowing their strategic contribution to the Space Economy with the development of new technologies and systems.

Developments in space telecommunication are one of the institutional duties of ASI. Since the mid-70s, Italy has been promoting the exploitation of the higher frequency ranges allocated to space services. Italy pioneered the Ka-band (20/30 GHz) back when it was not yet considered suitable for commercial applications.
Space infrastructures for satellite communications represent a key sector where ASI acquired expertise along several missions, such as Satellite Italiano di Ricerca Industriale e Operativa (SIRIO), ITALSAT, Aldo Paraboni Payload of Alphasat, Athena Fidus, and project initiatives such as DAIA and Video Interactive Distribution and W-band Analysis and Verification. In particular, in the framework of the high-frequency satellite communications, ASI focused on the efficient exploitation of extremely high frequency (EHF) bands for broadband transmission over satellite links with the operation of Ka and Q/V band systems, with the inherent studies on propagation, and with the support to advanced studies for the development of W-band (75-110 GHz) satellite communication systems.

The geostationary satellite SIRIO, developed under the First Italian space private public partnership between Consiglio Nazionale della Ricerche and Compagnia Industriale Aerospaziale, was launched on August 25, 1977 from the Kennedy Space Center. This project allowed the experimentation of propagation impairments through atmosphere at 12 (downlink) and 18 (uplink) GHz. With a designed lifetime of 2 years, SIRIO was operative for more than 10 years and allowed the most important space agencies in the world to investigate electromagnetic propagation at those frequencies. The success of SIRIO, in addition to proving the level of excellence of the Italian space sector, gave further impetus to the field of satellite communications and also had important impact on the context of the cooperation among national structures operating in space research.

ITALSAT F1 was launched on January 16, 1991, providing a “global” national beam and 6 spot beams at 20 GHz (downlink) and 30 GHz (uplink) to cover the Italian territory. The availability of beacons for telemetry and propagation, at 18.7 GHz, and for propagation, at 40 and 50 GHz, allowed the collection of a large amount of scientific data, which are still useful and used by researchers from all over the world. ITALSAT F2, launched on August 8, 1996, embarked the European Mobile System. ITALSAT F2 was placed in geostationary orbit at 16.4°E, providing L band (1.4-1.6 GHz) links for mobiles, and Ku band (12-14 GHz) links for ground stations, with coverage on Europe and North Africa. Scientific experiments have been performed also with ITALSAT F2, and several important propagation studies did benefit from data coming from both satellites, considering that, besides their operational applications, these programs allowed to test and anticipate the main broad band satellite and mobile user service applications.

In 2004, ASI decided to investigate higher frequencies for communication payloads and continued developing projects relative to technologies and devices for telecommunications at very high frequency bands (such as Q/V, W, and optical), indispensable for future broad band systems. In this framework, ASI funded 2 important feasibility studies for the exploitation of the W-band (75-110 GHz) for satellite communications: DAIA and Video Interactive Distribution and W-band Analysis and Verification. The first project was supported up to phase B (preliminary definition) and aimed at developing a LEO satellite mission operating at W-band for the collection of high volumes of data from remote sites (to demonstrate the capability of the W-band channel to be used reliably for a telecommunication link) and the characterization of the satellite propagation channel at this frequency band. The objective of the second project was to design and deploy different missions (embarked on LEO, GEO, and HAP platform) for scientific experimental use of the W band channel in satellite data communications.

The adoption of the Q/V-band for commercial systems was previously considered to be hardly viable because the traditional design approach tends to oversize links to counteract the deep atmospheric fades. However, the reference scenario has rapidly evolved with the provision of novel Adaptive Interference/Fading Mitigation Techniques (e.g., DVB-S2), allowing Q/V-band systems to operate efficiently with good service performance. Furthermore, the necessary technology is quickly evolving, also owing to the fruitful synergies with the commercial world.

Within the ASI Q/V band program, a telecommunication and propagation experimental payload was developed in cooperation with ESA to be embarked on the Alphasat satellite, a commercial telecommunication geosynchronous satellite based on the ESA Alphasat Platform.

The Aldo Paraboni Payload is a demonstration communication/propagation payload designed to study and test the potential of Q/V band frequencies for future space telecommunication applications. The technical name is TDP#5, but ASI, in agreement with ESA, decided to rename it as the “Aldo Paraboni Payload” in memory of the professor of Politecnico di Milano, who was a reference point for the international scientific community in the field of electromagnetic wave propagation ever since the first Italian SIRIO satellite. The Aldo Paraboni Payload was proposed by ASI for experimentation in the Q/V band and developed as part of the Italian funding for the ESA ARTES 8 program according to the scientific and technical requirements provided by ASI.

The Aldo Paraboni payload represents the “space segment” of an ASI program dedicated to experimenting and validating the frequencies in the Ka/Q/V (20 and 40-50 GHz) band for their use in satellite communications. The “ground” or “mission segment” consists in a network of ground stations capable of performing contemporarily communication and propagation experiments by using the Aldo Paraboni signals. The Italian Q/V band program is the first telecommunication experimental program at Q and V band in the world using in-orbit assets. With the program in the Q/V band, Italy is maintaining its position at the forefront of space telecommunications by conducting experiments at such high frequencies and by employing such an articulated architecture of ground stations.

Moreover, ASI contributed to the realization of the Access on Theaters and European Nations for Allied forces-French Italian Dual Use Satellite, which allows broadband communication services to Italian institutional/civilian users over the Italian national coverage at Ka band by exploiting dedicated transparent star and mesh communication channels. Access on Theaters and European Nations for Allied forces-French Italian Dual Use Satellite is a satellite system for broadband communication services aimed at military, governmental, and civilian users, promoted by the ASI and by the Centre National d’Études Spatiales in the frame of cooperation agreements signed by the 2 agencies and the Italian and French Ministries of Defense. The satellite was launched on February 6, 2014 from the Kourou Space Centre in French Guiana and has an expected life of over 15 years. The satellite system architecture entails a high service provisioning flexibility, thanks to the coexistence of single-hop mesh transponders and double-hop star transponders, all fully compliant with state-of-the-art low-cost ground segment technologies based on standard DVB-S2 and DVB-RCS for the provisioning of both fixed and mobile communications.
Finally, in the framework of the European Commission initiatives, ASI is the coordinator of the ongoing QV-LIFT project, a Horizon2020 Research and Innovation Action started at the end of 2016, committed to increase the maturity level of key satellite communication technologies and to contribute to a more competitive positioning of satellite communication European manufacturers in the marketplace. The rationale is to exploit Q/V band (40-50 GHz) for the feeder link to reach the terabit/s connectivity in the short/medium term and introducing flexibility and scalability coming from the virtualization of baseband functions.

Given the above experience, ASI continues looking forward to possible cooperations, beyond the ones already existing and successful, both from the scientific international community and from commercial operators to maximize the investment return in high-frequency satellite communication systems.

2 THE ALPHASAT “ALDO PARABONI” EXPERIMENT

2.1 The scientific experiment: SciEx

The history of EM wave propagation on an Earth to satellite path dates back to the 1970s and involves several countries supporting different research activities, for example, the ATS-5, COMSTAR, and ACTS experiments promoted by NASA (USA), the ETS-I, and CS experiments launched by JAXA (Japan), the OLYMPUS, OTS-1, and OTS-2 experiments operated by ESA (Europe) and the already mentioned Italian SIRIO and ITALSAT campaigns by ASI. All these experiments provided large datasets, whose investigation led to many insights on the effects induced by the atmosphere on EM waves, as well as to the development of several models accepted as standard of the standardization bodies, such as the International Telecommunication Union-Radiocommunication Sector. Nevertheless, despite all the previous experiments, some issues and aspects needed deeper investigation:

- Few results were available above the Ka band (only the ITALSAT experiment allowed measurements in a limited number of site at 40 and 50 GHz).
- The observation period of the measurements campaign (especially because of receiver outage events) was very often below 95 to 98% of the yearly time.
- Few measurements were carried out with high sampling rate (higher than 10 samples per second) for a complete characterization of the signal spectrum and, in particular, of scintillation effects.
- Few measurements of cross-polar discrimination (XPD) were collected and even fewer of the whole atmospheric transfer matrix.
- For various reasons, there was a very limited period where measurements were simultaneously available in several European sites for a good characterization of spatial correlation of various atmospheric effects.
- Even if a good processing tool was developed during the Olympus propagation campaign, common data processing and analysis procedures were generally missing, thus leading to final statistical results not always of easy comparison.

The new Aldo Paraboni Scientific (propagation) experiment (SciEx) aims at addressing most of these issues by exploiting the dedicated payload, which consists of two beacons operating at Q and Ka bands, 39.4 and 19.7 GHz, respectively, covering the whole Europe. As for the ground segment, the two Italian terminals are located at Spino d’Adda and Tito Scalo. To enlarge the significance of the propagation experiment, the development of additional propagation ground terminals for Alphasat has been assigned by ESA, within the ARTES 5 program for Telecom technology, to Joanneum Research and Graz University of Technology. In the frame of this contract, a propagation terminal was also placed in Graz to perform joint measurements with the telecommunication station (realized in the framework of an ESA ARTES 8 activity with the support of the Austrian Aeronautics and Space Agency). After Austria, many other European experimenters joined (or will join in the near future) the propagation experiment, realizing ground stations distributed all over Europe: they are listed in Table 1 and shown in Figure 1.

The main objectives of the Aldo Paraboni propagation measurement campaign are as follows:

- calculation and characterization of the first-order statistics of attenuation at the two frequencies of 19.701 and 39.402 GHz (cumulative distributions conditioned to various conditions, e.g., months of the year and hour of the day);
- calculation and characterization of the second-order statistics (fade duration and slope, scintillation conditioned to attenuation, and long-term and instantaneous frequency scaling);
- calculation and characterization of space and time correlation of attenuation and of joint statistics with other (meteorological) parameters;
- acquisition of depolarization measurements and characterization of the relationship between XPD and copular attenuation during rain events and of XPD during ice events;
- acquisition of sky-noise temperature;
- acquisition of the numerical weather products, such as meteorological radar, radiometers, European Centre for Medium-Range Weather Forecasts, Meteosat, radio soundings, and rain gauges;
• theoretical assessment, on the basis of these measurements, of the gain deriving from the possibility to partition the power available on board among the various spot beams illuminating the served area;

• study of the parameters measured during the concurrent communication experiment (ComEx); and

• evaluation of the gain originating from implementing time and site diversity as a means to counteract extremely high atmospheric fades.

TABLE 1  List of receiving stations for the Alphasat propagation experiment

<table>
<thead>
<tr>
<th>Site</th>
<th>Country</th>
<th>Experimenter</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
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<tr>
<td>Tito</td>
<td>Italy</td>
<td>Politecnico di Milano</td>
<td>40°35'55&quot;N</td>
<td>15°43'23&quot;E</td>
</tr>
<tr>
<td>Spino d'Adda</td>
<td>Italy</td>
<td>Politecnico di Milano</td>
<td>45°24'48&quot;N</td>
<td>9°29'40&quot;E</td>
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<tr>
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<td>Austria</td>
<td>Joanneum Research</td>
<td>47°05'07&quot;N</td>
<td>15°27'54&quot;E</td>
</tr>
<tr>
<td>Milan</td>
<td>Italy</td>
<td>EOARD/NASA and Politecnico di Milano</td>
<td>45°28'43&quot;N</td>
<td>9°13'58&quot;E</td>
</tr>
<tr>
<td>Rome</td>
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<td>12°29'38&quot;E</td>
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<td>France</td>
<td>ONERA</td>
<td>43°34'14&quot;N</td>
<td>1°28'19&quot;E</td>
</tr>
<tr>
<td>Salon de Provence</td>
<td>France</td>
<td>CNES</td>
<td>43°37'12&quot;N</td>
<td>5°7'12&quot;E</td>
</tr>
<tr>
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<td>UK</td>
<td>STFC</td>
<td>51°09'00&quot;N</td>
<td>1°25'36&quot;W</td>
</tr>
<tr>
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<td>UK</td>
<td>STFC</td>
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<td>Slovenia</td>
<td>Jozef Stefan Institute</td>
<td>46°02'31&quot;N</td>
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<td>3°19'21&quot;W</td>
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<tr>
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<td>NASA/EOARD</td>
<td>40°52'12&quot;N</td>
<td>4°15'00&quot;W</td>
</tr>
<tr>
<td>Kjeller</td>
<td>Norway</td>
<td>FFI</td>
<td>59°58'48&quot;N</td>
<td>11°00'00&quot;E</td>
</tr>
<tr>
<td>Cluj-Napoca</td>
<td>Romania</td>
<td>Technical University of Cluj-Napoca</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIGURE 1  Location of the current receiving stations for the Alphasat propagation experiment [Colour figure can be viewed at wileyonlinelibrary.com]
The achievement of most of these objectives and the quality of their results are conditioned to the effective coordination among the experimenters. To this purpose, a specific working group, referred to as AlphaSat Aldo Paraboni propagation Experimenters, has been established and is coordinated by ASI and ESA. The group collected from several experimenters the will to participate in the measurement campaign with different receivers and to collaborate for the data investigation and for the development of large-scale propagation models.

2.2 The Q-/V-band communication experiment: ComEx

The aim of ComEx is to design, optimize, and test adaptive transmission schemes, i.e., propagation impairments mitigation techniques (PIMTs), over the Q/V band satellite channel.18 These techniques play a fundamental role in the effective exploitation of EHF band for satellite communications.19-21

The ComEx payload includes a transparent transponder with two channels, with a bandwidth of 10 MHz and operating in Q/V band with cross-strapping capabilities. The central frequencies of the Earth to space communication link are in V band, at 47.9 and 48.1 GHz. The central frequencies of the space to Earth communication link are in Q band, at 37.9 and 38.1 GHz. The polarization is linear vertical. The payload can generate three different antenna beams, with up to 2 beams that can be simultaneously active, in particular, a fixed beam pointing at a ground station located in Tito Scalo (Italy) and a second beam with selectable pointing between two ground stations, the one located in Spino d’Adda (Italy) and the one located in Graz (Austria). The onboard antennas provide a receive gain of 38.3 dBi end of coverage, and a transmit gain of 37.5 dBi end of coverage. The nominal output power of the satellite transponders is 10 W.

The ComEx payload transponder can be configured by using 1 of the following 2 modes:

- Cross-mode: The receive and transmit beams of each transponder serve different geographical areas (each channel is received and transmitted on a different antenna beam).
- Loop-back-mode: The receive and transmit beams of each transponder serve the same geographical area (each channel is received and transmitted on the same antenna coverage).

In cross-mode configuration, the payload allows full-duplex communication between the station located in Tito Scalo and, alternatively, the station located in Spino D’Adda or the one located in Graz.

The RF components of the two Italian ground stations are a large Q/V band antenna (4.2 m), with a gain of about 62 dBi, and an extended interaction klystron high power amplifier with a nominal power of 50 W (and a peak of 200 W). The RX figure of merit, G/T, is 33.3 dB/K. The antenna tracking system is based on a mono-pulse auto-tracking system. The baseband communication section is based on the DVB-S2 standard.21

The PIMTs currently under test are adaptive coding and modulation (ACM), uplink power control (ULPC) and space diversity. Moreover, experiments on the optimization of channel estimation and prediction techniques are performed as well. In the following sections, the objectives of the experimental campaign will be introduced.

2.3 Link quality estimation and channel prediction

The adaptation of dynamic transmission schemes is based on the use of a link quality estimator with the aim to properly select transmission parameters to follow the current channel conditions. In particular, the most suited transmission parameters are selected on the basis of channel measurements at the transmitter side (open-loop approach) or at the receiver side by sending a command through a return link to drive the algorithm (closed-loop approach).

Dynamic channel conditions are a consequence of a slow variation component (e.g., rain fading) and a fast variation component (e.g., scintillations). Propagation impairments mitigation techniques are not able to follow fast channel variations, but such type of variations may be taken into account during the design phase of the link.

Several channel estimation metrics at the receive terminal may be considered for driving PIMTs in closed-loop configuration: received signal strength, carrier to noise ratio, signal-to-noise ratio (SNR), error vector magnitude, bit error rate, and frame error rate. On the other hand, data gathered from ancillary equipment, such as the radiometer data, the meteorological station, or the Q band beacon receiver, can be used to drive PIMTs in open-loop configuration.

Because the DVB-S2 standard allows to insert pilot symbols within the frame structure, a data-aided (DA) SNR estimation algorithm has been used in the first part of the experimental campaign. In a DA system, a standardized pilot sequence is included in each transmitted frame, with the aim to ease SNR-plus-interference ratio estimation. The DA SNR estimation algorithm used in the experiments is the DA maximum-likelihood SNR-plus-interference ratio estimator, as suggested by the DVB-S2 standard. The main results on DA estimator characterization are reported in Rossi et al.22

2.4 ACM control-loop optimization

The objective of the ACM experiments is to design and optimize control algorithms for the specific 40 to 50-GHz communication channel. The ACM mode switching algorithm should optimize the trade-off between spectral and power efficiency, thus optimizing the modulation and coding (ModCod) selection on the basis of channel conditions.
The ModCod used to transmit each DVB-S2 PLFRAME is selected by the receiver on the basis of a link quality estimation metric and the current and/or predicted channel condition. A total of 28 ModCods can be used in DVB-S2 standard; hence, the correct selection of the most suitable transmission scheme is performed on the basis of different performance metrics:

- maximization of mean spectral efficiency;
- minimization of packet loss events percentage;
- minimization of efficiency loss events percentage (frames transmitted by using a lower efficiency ModCod with respect to the one that could have been used on the basis of the actual SNR);
- maximization of correct ModCod transmission percentage (when the used ModCod is exactly the one that provides the best spectral efficiency for the current channel conditions); and
- minimization of switching between ModCod, to minimize the need for reverse link signaling when the estimated SNR is jittering around one of the ModCod threshold.

The 2 basic steps of ACM control loop optimization are as follows:

- Identification of a subset of useful ModCod (among the whole available set for DVB-S2 standard); this step is required because, in general, adjacent ModCods should be separated by at least the magnitude of SNR change in the adaptation time.
- Optimization of physical layer selector; in practical applications, physical layer selector is commonly based on operative SNR thresholds used for ModCod switching that are calculated by adding a static and fixed margin to the ideal values (ie, calculated by using an AWGN-like channel) required to reach a target; this approach is called "shifted threshold." An alternative approach to ModCod switching based on "hysteresis loop" can be used to prevent undesired oscillations of the transmitting ACM mode in case of SNR jitter (not compensated by SNR estimation averaging) between adjacent ACM thresholds. Both these approaches for the optimization of ACM control loop are currently under investigation.

2.5 Spatial diversity and uplink power control

The Q/V-band communication experiments also aim at analyzing, testing, and optimizing ULPC and spatial diversity. Uplink power control is a feeder link PIMT with the objective to adaptively change the power transmitted by a ground station on the basis of link attenuation to maintain a constant satellite input power flux density. The ULPC implementation strategy must carefully take into account onboard amplifiers characteristics to prevent saturation. Different strategies of power control are currently under test: open-loop approach with use the downlink beacon signals in Q and Ka bands and closed-loop approach based on the evaluation of uplink channel attenuation on the basis of the self-transmitted downlink.

![FIGURE 2 Experimental setup for spatial diversity experiments](Colour figure can be viewed at wileyonlinelibrary.com)
signal or the feedback coming from the receiving ground station. Uplink power control algorithms are optimized on the basis of metrics such as power control accuracy, maximum level of compensated fading, and implementation timing.

Spatial diversity techniques have an ever-growing importance in the future HTS systems that foresee the use of EHF in the feeder link. As a matter of fact, the only possibility to maintain the high feeder-link availability level required by these systems (higher than 99.5%), without imposing a very conservative and inefficient margin on the link budget, is to use a diversity approach.24,25

In this framework, spatial diversity experiments performed in Q/V-band are conducted to gather information useful to optimize a very interesting spatial diversity approach called smart gateways.26 The latter is a feeder-link diversity scheme based on a certain number of gateway stations connected with a terrestrial fiber network so that it is possible to reroute data to counteract deep fades on one (or more) gateway(s). Considering that the system architecture of the Q/V band ComExs has only two ground stations, it is not possible to fully implement and test a smart gateway scheme, but it is possible to realize a "reduced" experimentation by using a cross-mode payload configuration: one ground station is used as transmitting "master station," while the other is used as a transmitting "slave station"; the latter is used also as receiving station of the experiment whose setup is depicted in Figure 2. This configuration can be used to test handover procedures that have to be performed when deep fade occurs in the master station uplink channel.

3 | CONCLUSIONS

The continuous evolution of satellite communication systems has greatly benefitted from the key role of the ASI, which has been continuously supporting research activities on high-frequency SatCom systems, as well as their technological development, since the very birth of the satellite industry, more than 40 years ago. The commitment started with the SIRIO propagation experiment, launched in 1977, and extended up to today, with the support to the Alphasat Aldo Paraboni experiment, in collaboration with the ESA. This experimental campaign consists of two main branches: the Scientific (propagation) experiment SciEx, which aims at improving the understanding of the Earth-space propagation channel at Ka band and Q band, taking advantage of the two coherent continuous-wave space-borne beacons operating at 19.701 and 39.402 GHz and a large number of ground stations (more than 20, at the moment) deployed throughout Europe; the ComEx, whose main goal is the thorough investigation of several fade mitigation techniques (eg, ULPC, site diversity, and ACM) that need to be implemented in the near future SatCom systems to overcome the extremely high fades induced by the atmosphere. This goal is meant to be achieved by exploiting three comprehensive ground stations installed in Italy (Spino d'Adda and Tito Scalo) and in Austria (Graz) working with operational frequencies in the Q (37.9 and 38.1 GHz) and V bands (47.9 and 48.1 GHz).

Key results are expected from this large experimental campaign supported by ASI, which will push the development and implementation of the near future high throughput satellite systems proving global terabit connectivity.

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Giuseppe Codispoti received the degree in Electrical Engineering from the University of Calabria, Italy and a Master of Science’s degree in Electrical Engineering from the California Institute of Technology in Pasadena, USA. During his graduate studies, he was involved in class projects at the Caltech/ NASA Jet Propulsion Laboratory in Pasadena with the responsibility of the communication aspects. From 1993 to 2000 he was with Alenia Spazio, Rome (now Thales Alenia Space Italia) at the “On board Active Antennas Department” as designer, project and program manager in either Telecommunication or Remote Sensing programs. In March 2000, he joined ASI, the Italian Space Agency, where he has been involved in projects regarding microgravity, remote sensing and telecommunications. At the moment, he works in the Telecommunication and Navigation Division and he is the responsible of the Q/V Band Program of the Agency. He has been appointed as delegate and expert of the Italian Government in delegations of international bodies such as ESA, European Space Agency and UNO, United Nations Organization. He is member of Technical and Scientific Committees of public Foundations. He is tutor of PhD students of Italian universities.

Giorgia Parca Master degree in Telecommunications Engineering (2006) and PhD in Telecommunications and Microelectronics Engineering (2010) at University of Rome Tor Vergata, Electronic Engineering Department. Main research topics have been fiber optics, optical wireless, inter-satellite broadband technologies. Post-Doctoral fellowship at the Portuguese Telecommunications Institute, on optical telecom systems and devices for all optical data/image processing. She joined the Italian Space Agency in 2013, firstly with the Telecommunications and Navigation Division and currently with the Scientific Research Division. Main research areas are on enabling technologies for space communications, with particular focus on Ka, Q/V band, optical broadband telecommunication systems, Deep Space communications, and ground operations. She is a co-author of several papers on international journals and conferences proceedings.
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