Inter-Satellite Links and ARES Capabilities

The architecture of a satellite communication system consists of a set of elements belonging to the space segment and/or the ground/user segment which interact as an integrated system. Such system can be addressed as integration of different technologies (e.g. radio and optical), integration of services (e.g. integration of localization, Earth observation and communication services), integration of space and non-space systems (e.g. satellites aeronautical, stratospheric, terrestrial). So far, integration of space and non-space systems was mainly aimed at complementing the terrestrial coverage where this is not convenient or not possible. The result is usually an over-use of the terrestrial infrastructure and a non-efficient exploitation of the satellite resources. This concept of integration is too limited to fulfill quality of service requirements and user expectations in future multi-purpose systems. Essential to the design of integrated architectures where satellite, stratospheric and terrestrial resources are more effectively exploited is the clear understanding of the advantages and drawbacks that each system (satellite/stratospheric/terrestrial) intrinsically has in providing one specific service of a multiple service set.

LEO and MEO satellite constellations represent the only two layers of the architecture able to provide global coverage including polar regions since the GEO layer cannot provide the coverage of the two Poles. On the other hand, three GEO satellites can provide continuous coverage of the entire globe excluding polar regions.

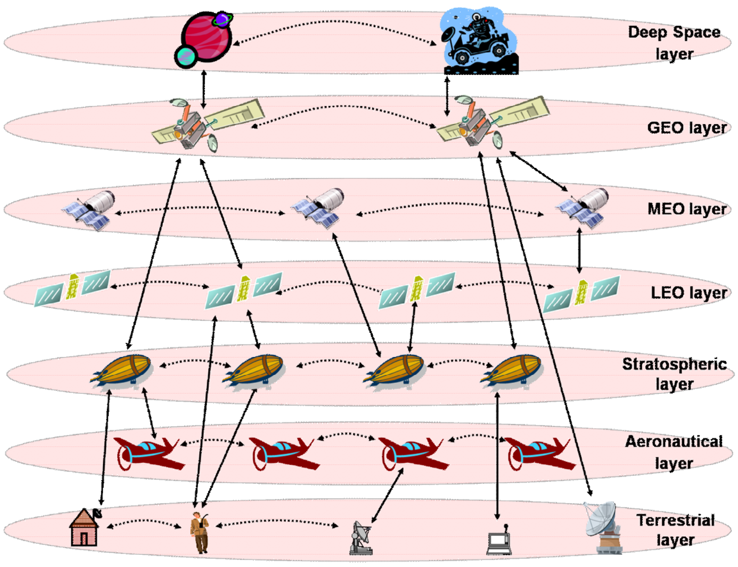

Figure 1: Generic multilayer architecture of a space-based communications system.

In a multilayered architecture, any element is a node of the multilayered network that can be exploited as part of the system concept providing several services to other subsystems through communication links. Every link of the network can be unidirectional or bidirectional. Figure 1 shows a generic multilayer architecture of a space-based communication system.

When satellites or HAPs equipped with On Board Processing (OBP) capabilities are used, Inter-Satellite Links (ISLs) or Inter-High Altitude Platforms (Inter-HAPs or IHLs) links can be provided and the system becomes a switching network in the sky where each satellite/HAP is a router node. An ISL allows communication between two satellites on the same LEO, MEO or GEO orbit/layer intra-orbit link (or intra-layer link) or on different orbits/layers (inter-orbit link or inter-layer link). A combination of inter-layer and intra-layer links can be used to bypass the most traffic congested layer of the architecture and to allow each system collaborating with other systems with the aim to: increase the quality of the service, decrease the unavailability of service and to integrate different services in a single system of systems. Both HAP and satellites systems need a more or less complex terrestrial infrastructure. The provision of ISLs/IHLs releases the need for a dense terrestrial infrastructure as a lower number of ground-stations are needed to support the communication. Moreover, only one uplink and one downlink are required to provide communication between two ground users, thus reducing the average propagation delay. Most of the on-board imaging systems (radar, optical, etc.) generate a large amount of data, hence, strict requirements on transmission capacity are needed to guarantee the proper download towards the ground segment. Moreover, timing is a key factor for many applications in support of a multitude of time-critical services. Hence, many ground stations are needed to satisfy such a requirement. It is well known that ground stations can be expensive to operate, especially when the satellites are maintained in a polar orbit, with ground stations in remote areas such as the Arctic. The possibility to use other satellites to relay the data captured by one satellite can lead to an efficient transmission of a high volume of data, reducing the number of ground stations.

In the dimensioning of ISL links, it has to be taken into account the changing relative positions of the two inter-linked satellites; hence, the variability of some parameters as azimuth and elevation, range and Doppler frequency shift has to be carefully evaluated. Radio Frequency (RF) technology is the more consolidate technology usable for inter-satellite communication links. An RF link could reach high data rate only using the very large bandwidth available in the millimeter wave region. In particular Q/V-band or W-band frequency range but also the Ka-band are extensively used; this permits also to avoid interference with other systems. The upcoming “beyond Ka-band” RF links can be a good competitor for the optical systems, due to the possibility to use a very large uncrowded spectrum (some GHz) to reach a very high throughput, to reduce the antenna size or beam-width (with regard to lower frequency RF systems) and to reduce the strict pointing requirements of the optical link systems. RF links can provide omni-directional coverage when considering multi-antenna combination. Although RF equipment is subject to co-channel interference, multipath, atmospheric and man-made noise, a careful system design and use of technologies (such as spread spectrum modulation) can significantly reduce interference effects in most cases. Furthermore, long term experience with radio transmission for space-to-ground links makes RF-based inter-satellite communication more reliable and easier to implement in space.

A typical circuital architecture used for ISL applications is visible in Figure 2. The digital section concerns the base-band signals manipulation, including the analog-to-digital and digital-to-analog conversions. The transmission section (in red) is composed by a Band-Pass Filter (BPF) to clean the transmitting signal from the unwanted products generated by the digital conversion. The Up-Converter (UC) indicates a general block used for shifting frequency towards higher values. Such a block could contain a Frequency-Multiplier (FM) necessary to shift the Synthesized frequency (Synt) to the proper required value. After a further filtering section (able to cancel unwanted nonlinear products), the signal passes then through the High-Power Amplifier (HPA), in order to become suitable for the long - distance transmission. The receiving section (in blue) is composed by a Low-Noise Amplifier (LNA) capable to amplify signals with an associated low noise addition. A first BPF could be used to avoid unwanted nonlinear products, then the Down - Converter indicate a general block used to shift the frequency towards lower values. Also in this case, a FM could be necessary to set the Local Oscillator (LO) frequency. A further BPF can filter the wanted Intermediate Frequency (IF) and Automatic Gain Control (AGC) can adjust the gain of the chain before sampling and conversion. The Switch (SW) is the element used to decouple the transmitting and receiving branches.

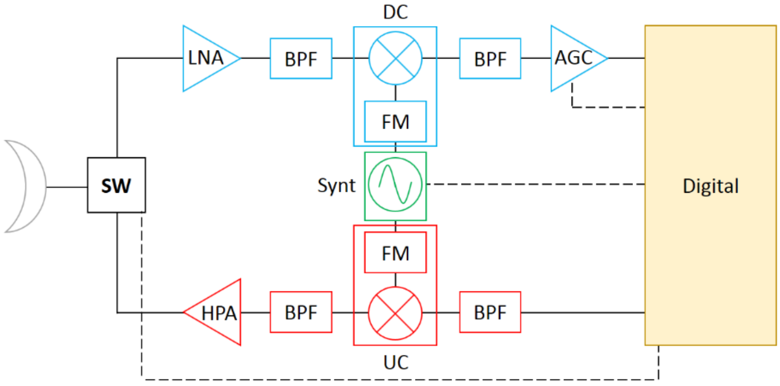

Figure 2: Typical circuital architecture for Inter-Satellite Link applications.

Several Components Off-The-Shelf (COTS) as components, units and subsystems are already available in commerce and have been analysed. Such COTSs are suitable to design a microwave front-end for ISLs. After a COTSs overview, it is possible to notice that there is a wide possibility to match the available components in terms of frequency bands, at least. Special requirements in terms of bandwidth (especially for wideband systems) can restrict the set of usable components and lead to design ad-hoc circuitry. ARES’ main R&D areas are relevant to space systems and technologies and related ground applications. The merging of Rome Tor Vergata University and a SME company allows to exploit the necessary synergies to respond, in integrated manner, to the new competitive scientific and technological challenges, within both domestic and international areas. ARES has a long-time heritage in microwave design and its know-how covers the whole ISL RF and optical front-end for both the space and ground segments. In particular, ARES’ capabilities concern:

- device/units and subsystem characterization and modelling: linear, nonlinear and noise up to 125GHz, scalable, bias - dependent modelling with different approaches (equivalent circuit, black-box, physical);
- circuit and subsystem design: Amplifiers (PAs, LNAs, VGAs, DPAs ...), Mixers (resistive, passive, active …), frequency multipliers, multifunction (Core chips, TR chips, Integrated Receivers …) adopting state-of-the-art design methodologies. Long-track experience in Hybrid as well as MMIC design with many foundries (SLX/Leonardo, UMS, OMMIC, NGS, TRW, Triquint, Raytheon, …).

In this context, ARES has recently won an Italian regional call regarding the development of local GaAs and GaN technologies for the aerospace market, under the project named GANIMEDE (**G**a**A**s-Ga**NI**nnovation **M**arket **DE**velopment).