PROJECT FINAL REPORT

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1. Final publishable summary report

1.1 Executive Summary (1p)

The evolution of SAR has shown a clear trend towards higher performance at lower cost, less mass, size and power consumption imposing strong requirements in the today's antenna technology since larger antennas means complex, bulky, difficult to route RF harness, and strong mechanical and thermal requirements for in-orbit deployable antennas. Larger bandwidths associated with larger antennas and scanning angles requires True-Time-Delay (TTD) beamforming, resulting in bulky and complex solutions.

The use of photonic integrated circuits (PIC) technology in the beamforming is a clear key enabling technology due to TTD can be implemented by using integrated photonics achieving order-of-magnitude improvements in size and mass, antenna system integration and reduction of the risks associated to the in-orbit antenna deployment.

The aim of GAIA is the development of the photonic technology required in future array antenna systems for SAR applications, covering from the optical signal distribution to the antenna, the true-time-delay control of the signal for each antenna element by using integrated photonics (PICs) both in transmission and reception, with broadband characteristics and covering up to Ka band, the design of the optical harness suitable for large, deployable antennas and the development of an antenna array module in X band (which imposes strong requirement in the optical delay implementation). The final design will be a complete modular antenna system with true-time-delay characteristics photonically controlled which will be the base of a large, deployable SAR antenna with a net gain in size, mass, complexity and cost when compared with the traditional implementations which will be measured in an anechoic chamber.

GAIA has performed the necessary design and research to enable the development of new optical monolithic technology capable of implementing ultra-low waveguide propagation losses and fibre coupling insertion losses. Waveguide losses lower than 0.1 dB/cm, far from the present state of the art, in high contrast technology have been developed in order to achieve low losses and a compact design for implementing the optical delays in the range of hundreds of picoseconds required for the SAR application for large antennas. Also integrated optical switching techniques will be implemented on-chip required for switchable optical delays designs (one for TX and other for RX) have been packaged and pigtailed to be included in the antenna structure. Electro-optical conversion components have also been included in the antenna in order to have the adequate RF interface from/to the antenna element.

In particular, **GAIA main achievements** have been:

- Design, fabrication, packaging, integration and test of a Photonic Integrated Circuit (PIC) as main element of an Optical Beamforming Network (OBFN).

- Development of design, fabrication and test procedures for optimised PIC performance, considering propagation losses (< 0.1 dB/cm), crosstalk, light coupling, etc.

- Development and functional demonstration of OBFN building blocks (CSDU, FoDS, APFE and AES) confirming the suitability of a TTD Photonic Beamformer for SAR Applications.

The achievement of GAIA goals will contribute to increasing innovative capacity of future developments by addressing a significant progress beyond the State-of-the-Art in antenna technology for SAR applications, improving the figures of size-mass-cost and achieving the call objective of compact RADAR / SAR technology for future Earth observation missions which will contribute to strengthen the European leadership in GMES.

1.2. Context and Objectives

As part of the European Space strategy in GMES (Global Monitoring for Environment and Security), the development of state-of-the-art SAR (Synthetic Aperture Radar) instruments has become one of the key enablers for the success of the European leading position, fostering the competitiveness of the European Space industry. Example of the state of the art SAR instruments are the SENTINEL family, ENVISAT, TERA-SAR or COSMO-SkyMed.

Figure 1. Representative SAR instruments (by ESA). Terrasar-X (left),ENVISAT (center) and COSMO-SkyMed (right)

A SAR, principally, produces a virtual long linear array antenna by means of computer technique moving a smaller real antenna along a straight line and collecting and storing all signals with respect to amplitude, phase, frequency, polarization, and running time for gaining desired information with special processing algorithms.

The most essential SAR system component, however, is the real SAR antenna itself; it is, for example, the greatest weight driver for space borne SAR. The next Table provides a brief overview of the earliest SAR developments and the timeline of orbital missions.

Table 1: Different optical switching architectures

Satellite	Country	Year	Band	Polarization	Max Pulse bandwidth (MHz)
SRTM	USA Germany	2000	C-Band	HH VV	20
			X_Band	VV	8
ENVISAT	Europe	2002	C-Band	HH,HV,VH,VV	9
RADARSAT-2	Canada	2007	C-Band	HH,HV,VH,VV	100
CosmoSkyMed	Italy	2007	X-Band	HH,HV,VH,VV	400
TERRASAR-X	Germany	2008	X.Band	HH,HV,VH,VV	150 (300 experimental)
Sentinel-1	Europe/ESA	2011-2012	C-Band	HH,HV,VH,VV	100

The SAR system peculiarity is the capability to acquire the land information also in case there are not perfect weather condition with cloud presence (partially information could be collected also with not intensive rain). The typical operative frequency bands for SAR application are L-S-C-X Bands: the lower frequencies are affected by smaller atmospheric losses; but, considering similar performances, it is requested larger antenna dimension.

On the basis of these considerations, the last SAR systems for satellite applications have been realized in C and X Bands. It is natural that a substantial step to an **Antenna-SAR for the next future generation is the expected progress in increasing the operative bandwidth and in miniaturization of the SAR antenna**. The miniaturization will drastically reduce the mass and volume of the antenna including the RF system down to 10 % of the today's value.

The evolution of SAR has shown a clear trend towards higher performance at lower cost, less mass, size and power consumption imposing strong requirements in the today's antenna technology since larger antennas means complex, bulky, difficult to route RF harness, and strong mechanical and thermal requirements for in-orbit deployable antennas. Larger bandwidths associated with larger antennas and scanning angles requires True-Time-Delay (TTD) beamforming, resulting in bulky and complex solutions.

The use of photonic integrated circuits (PIC) technology in the beamforming is a clear key enabling technology due to TTD can be implemented by using integrated photonics achieving order-of-magnitude improvements in size and mass, antenna system integration and reduction of the risks associated to the in-orbit antenna deployment.

The aim of GAIA is the development of the photonic technology required in future array antenna systems for SAR applications, covering from the optical signal distribution to the antenna, the true-time-delay control of the signal for each antenna element by using integrated photonics (PICs) both in transmission and reception, with broadband characteristics and covering up to Ka band, the design of the optical harness suitable for large, deployable antennas and the development of an antenna array module in X band (which imposes strong requirement in the optical delay implementation). The final design will be a complete modular antenna system with true-time-delay characteristics photonically controlled which will be the base of a large, deployable SAR antenna with a net gain in size, mass, complexity and cost when compared with the traditional implementations which will be measured in an anechoic chamber.

GAIA will perform the necessary design and research to enable the development of new optical monolithic technology capable of implementing ultra-low waveguide propagation losses and fibre coupling insertion losses. Waveguide losses lower than 0.1 dB/cm, far from the present state of the art, in high contrast technology will be developed in order to achieve low losses and a compact design for implementing the optical delays in the range of hundreds of picoseconds required for the SAR application for large antennas. Also integrated optical switching techniques will be implemented on-chip required for switchable optical delays designs (one for TX and other for RX) and will be packaged and pigtailed to be included in the antenna structure. Electro-optical conversion components will also be included in the antenna in order to have the adequate RF interface from/to the antenna element.

GAIA relies on the unique combination of Ultra-low loss Si_3N_4 monolithic planar lightwave circuits with switching capabilities for achieving an ultra-compact Photonic Integrated Circuits (PIC) implementing tuneable true-time delay (TTD) modules for achieving characteristics such as cost-effectiveness, small footprint, device scaling and modularity suitable for antenna beamforming for the present and future broadband Synthetic Aperture Radar (SAR) missions.

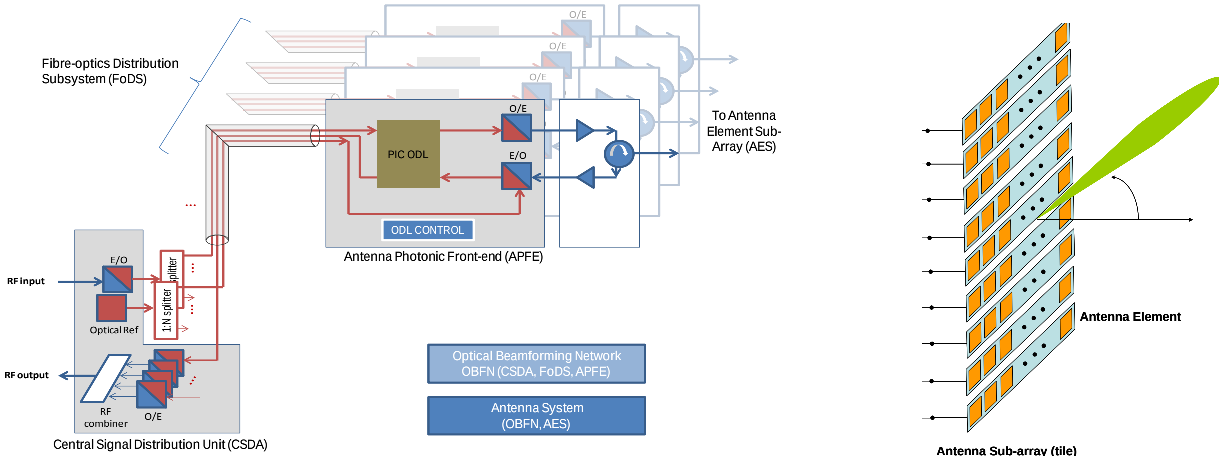


Figure 2. Scheme of the system to be designed (left) and detail of the Antenna Subarray (tile).

Specifically, Antenna Photonic Front-Ends (APFE) will be designed integrating the GAIA TTD PICs with Electro-Optical and Opto-electronic converters in order to have a modular, ultra compact, repeatable, bidirectional TTD front-end for the antenna sub-arrays forming the antenna tile. In a final system, several antenna tiles will form the deployable SAR antenna which could have a typical length of several meters.

The APFE are feed via optical fibre connecting all the antenna sub-arrays with a Central Signal Distribution Unit (CSDU) which is in charge of converting the RF signal to be transmitted by the antenna to optics, distribute a common optical reference to all the APFEs which is used to carry (by amplitude modulation) the incoming RF signals from all the antennas in reception mode to the CSDU. All the received modulated optical signals from the APFE in reception are converted back to RF by as many photoreceivers (O/E) as APFEs and combined with an RF combiner in order to have the common RF output from the beamforming.

By adjusting the optical delay within the PIC, the beam is steered to the desired angular position. Independent control to TX and RX will be done by using independent optical delay lines with at least 4 bits of control level. A system for a centralized control of all the beams will be also studied during the project.

The Fibre Optics Distribution Subsystem (FoDS) will be designed with taking into account the requirements of signal stability, space environment and routing issues of the SAR application. Then, the Optical Beamforming Network (OBFN) will be composed by the CSDU, the FoDS and the APFE. This OBFN should feed the Antenna Element Sub-array (AES) which will be fabricated for X band with a minimum bandwidth of 400 MHz and an objective of 800 MHz.

The GAIA objectives have been clearly identified, individualized and described in a measurable manner:

- **Objective 1**: The implementation of compact, suitable for space, SAR signals-over-Fibre distribution system.
- **Objective 2:** Special optical harness design to satisfy the stringent requirements of delay stability in SAR applications and compatible with deployable structures.
- **Objective 3:** The design of photonic integrated circuits (PIC) for delay control with low loss and large delay compatible with large antennas requirements.

- **Objective 4:** Development of beyond state-of-the-art PIC manufacturing methods for achieving the optical waveguide ultra-low-loss required to implement large delays with low losses.

- **Objective 5:** Fabrication of the designed photonic integrated circuits for delay control with low loss and large delays compatible with large antennas requirements.

- **Objective 6:** Packaging of the PICs inside a hermetic package compatible with space environment specification.

- **Objective 7:** Development of efficient, broadband, space-suitable photorecievers.

- **Objective 8:** The design and manufacturing of the SAR antenna module.

- **Objective 9:** Development of an integrated optical beamforming antenna system.

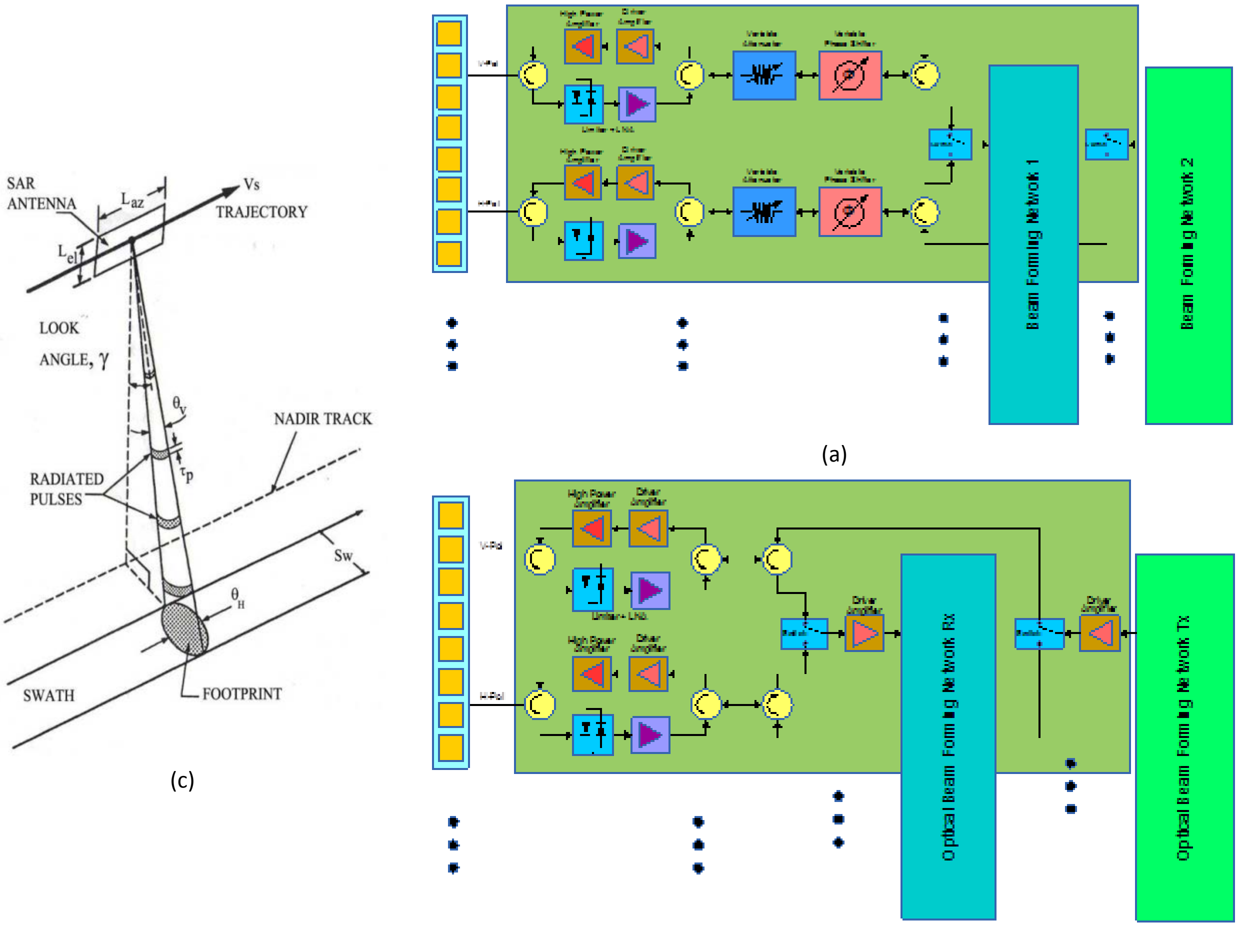
- **Objective 10**: Measurement and evaluation of an integrated optical beamforming antenna system.

- **Objective 11**: GAIA technology exploitation.

1.3. Main S&T results

During the **First Reporting Period** (October 2012 – September 2013) the main activities were focused on the identification of the application scenarios (suitable missions) and its top level requirements, the system definition and the preliminary design of the subsystems integrating the beamformer.

Different application scenarios were identified suitable to apply the photonic technology to be developed in GAIA for SAR antenna beamforming including a scenario for big platforms, small platforms or satellites in tandem, to cover as many applications as possible. A number of high-level requirements were included covering such scenarios, most of them applicable not only to the Antenna system, but also at full payload level.



(c)

(a)

(b)

Figure 3. System geometry and SAR Antenna operating sketch (a), Typical Architecture of SAR Antenna with dual beam-formers (b) and with single dual Optical beam-formers (c)

Table 2. Reference requirements for the three missions considered in the project.

Parameter	Performances Mission #1	Performances Mission #2	Performances Mission #3
Operating Band	X-band, 9600 MHz	X-band, 9600 MHz	X-band, 9600 MHz
Signal bandwidth	500 MHz	400 MHz	800 MHz
P/L Mass, including antenna	30 kg	30 kg	250 kg
P/L Peak Power	1000 W	30 W	2800 W
Access Area	20° ÷ 45°	20° ÷ 45°	15° ÷ 55°
Spatial Resolution	1 m ÷ 3 m	1 m ÷ 3 m	0.5 m
Swath width	5 km ÷ 8 km	5 km ÷ 8 km	5 km ÷ 8 km
Noise Equivalent σ_0	- 20 dB @ 1m res.	- 25 dB	- 15 dB
	-30 dB @ 3m res.		

According with the above beamformer requirements, preliminary simulations at system level were made for the photonic Front-End for 500 antenna elements in order to define the Central Signal Distribution Unit (CDSU), Fibre-optics Distribution Subsystem (FoDS) and Antenna Photonic Front-End (APFE) specifications.

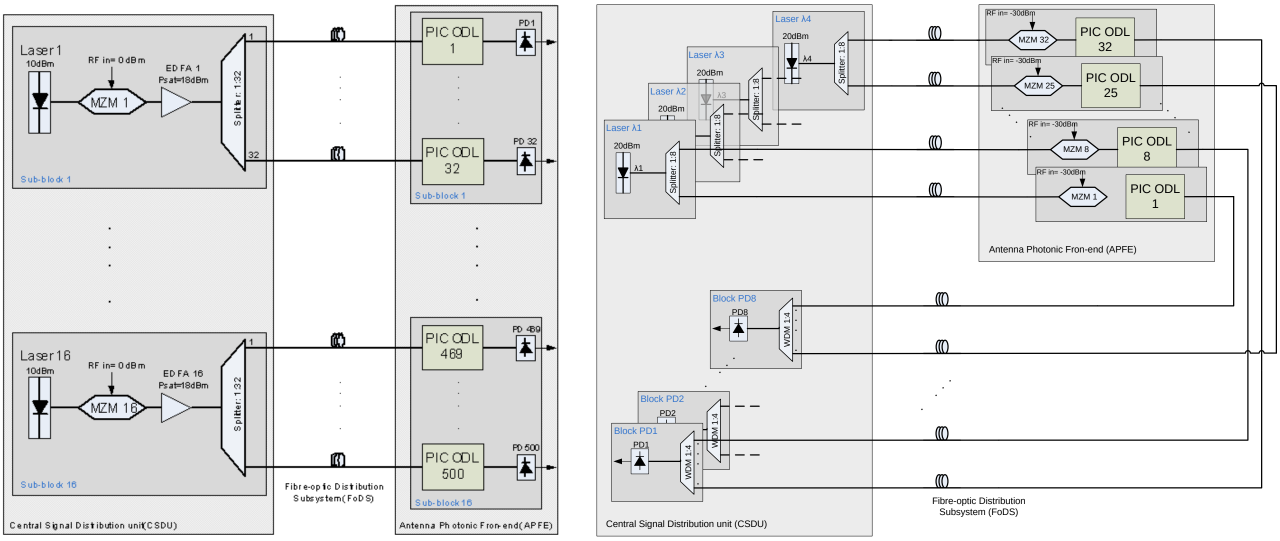


Figure 4. Scheme of the transmission subsystem for 500 antenna elements (left) and scheme of the reception subsystem for 32 antenna elements, which should be replicated 4 times for addressing 500 elements (right).

The preliminary design of the CDSU and APFE was initiated in this period, which included important parts of the system as the photonic integrated circuit (PIC) as part of the APFE, the photoreceivers, the E/O converters or the antenna element, which were designed in detail. Figures 5-8 show pictures of the designs and lay-outs.

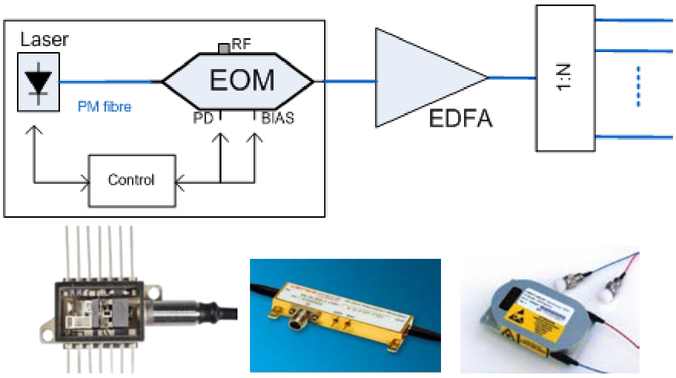


Figure 5. CSDU diagram for the Tx subsystem (top) and pictures of the most representative components (down) including, from left to right, laser, modulator and Optical Amplifier

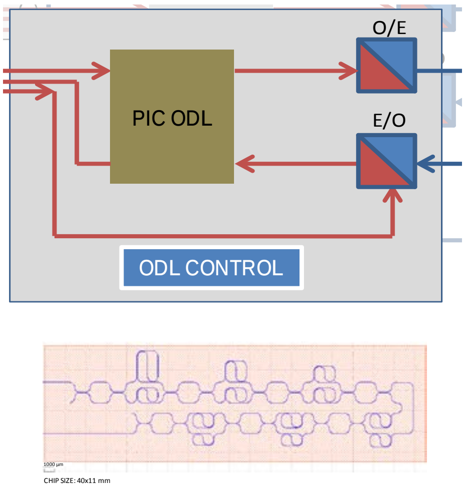


Figure 6. Scheme of the APFE (top) and PIC layout (down)

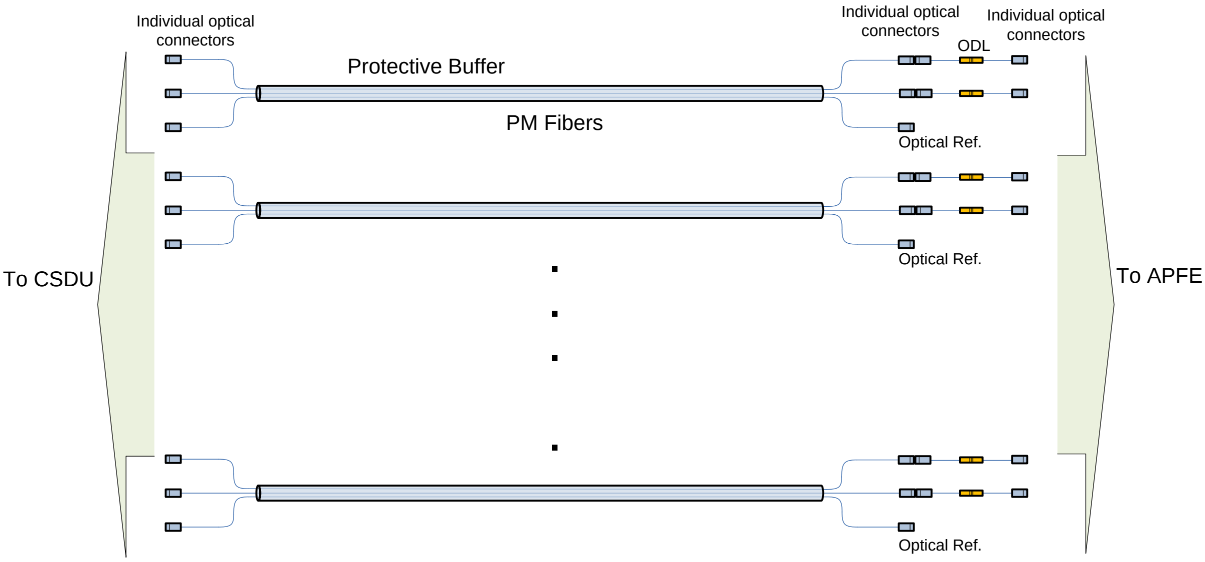


Figure 7. Scheme of the design of the FoDS

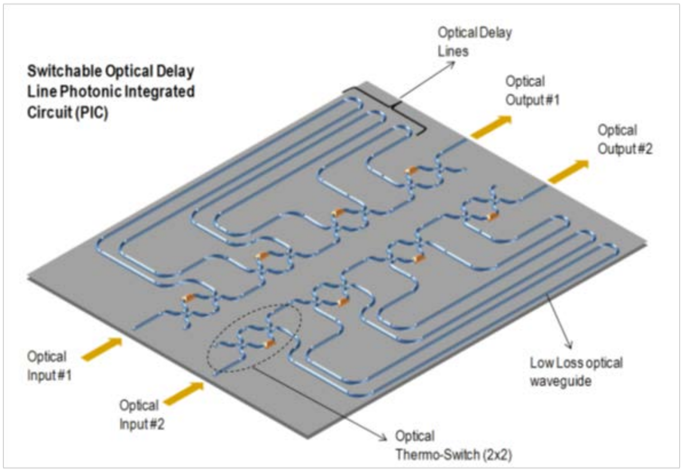


Figure 8: Schematic view of the proposed Photonic Integrated Circuits (PIC)

In parallel to the PIC design, important advances in the photonic manufacturing process was made as well as in the photonic packaging design. Figure 9 shows pictures of the fabricated building blocks on Si_3N_4.

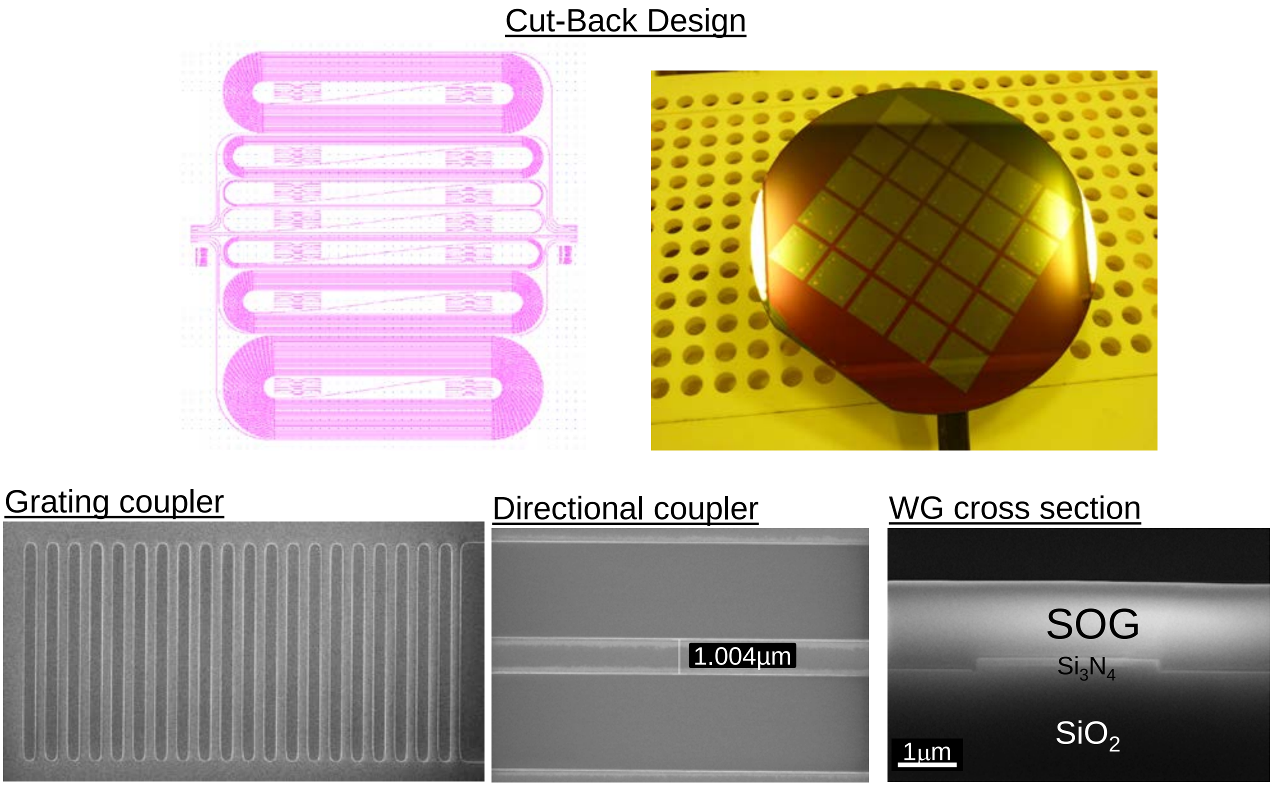


Figure 9 Si3N4 waveguide fabrication

During the **Second Reporting Period** (October 2013 – September 2014) the main activities were focused on the detailed design and manufacturing of the CDSU, FoDS and APFE which were designed to be representative of a Photonic Front-End according with the application scenarios and specifications identified during the first Period.

In particular, the detailed design of the CDSU and the APFE was almost finalized during this period, including the most important parts of the system. Moreover, an AES (Antenna Element sub-array) prototype was manufactured and the FoDS, which was manufactured and tested, was ready for its assembly in the final demonstrator system to interconnect the CSDU with the APFE, since all specifications were successfully fulfilled.

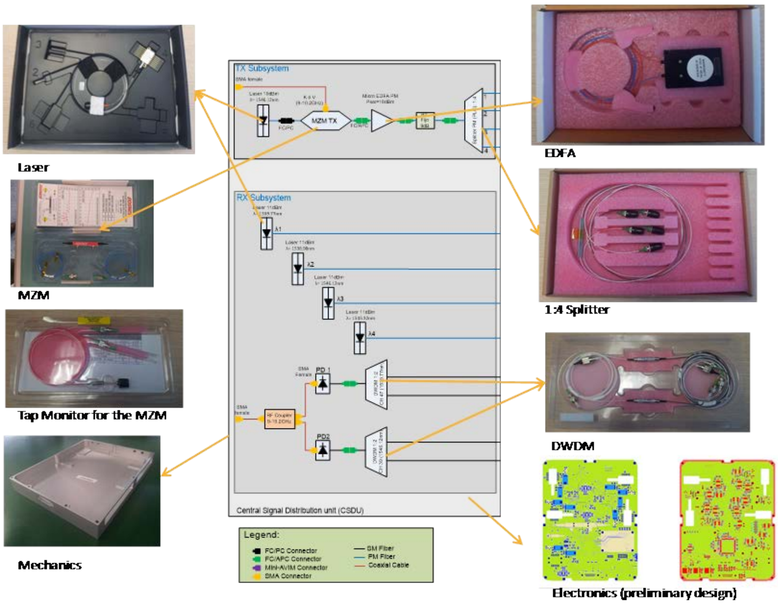
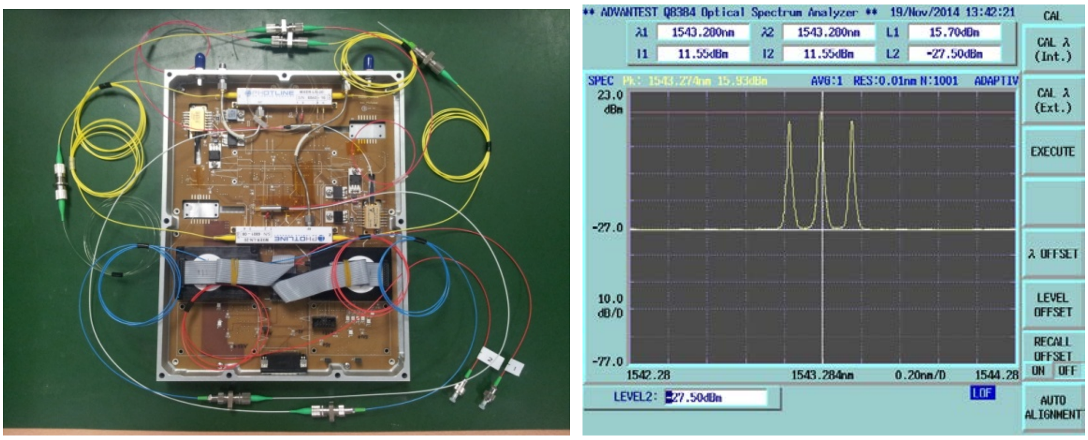


Figure 10. CDSU components purchased.


** ADVANTEST Q8384 Optical Spectrum Analyzer ** 19/Nov/2014 13:42:21

λ1 1543.200nm λ2 1543.200nm L1 15.70dBm
l1 11.55dBm l2 11.55dBm L2 -27.50dBm

SPEC Pk: 1543.274nm 15.93dBm AVG:1 RES:0.01nm N:1001 ADAPTIV

LEVEL2: -27.50dBm

Figure 11. Intermediate board used for the assessment of the CDSU control electronics (left) and optical spectrum generated with this test board (right).

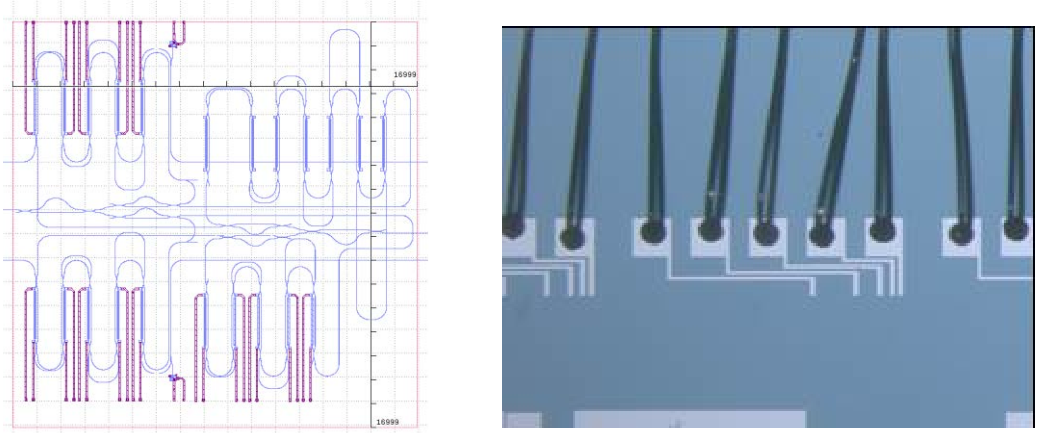


Figure 12: Draft layout of APFE chip for the whole Photonic Front-End (unit in μm), and details of the wire-bonded Al pads on LTO samples.

Finally, in reference to the photonic manufacturing process, the propagation losses met the project objective of 0.1dB/cm. Fabrication of directional couplers and thermo-optical switches was carried out and measurements were performed in order to assess the target performances were met. Figures 13-19 show pictures of the fabricated structures and the measurements carried out.

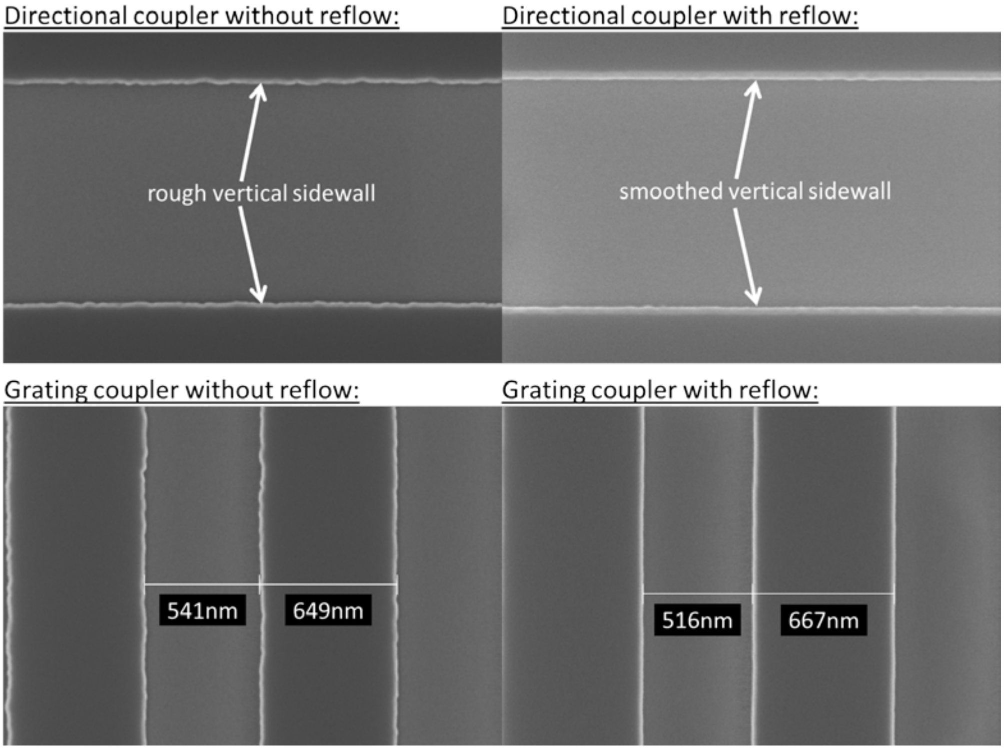


Figure 13: Waveguide structures fabricated with and without resist reflow process

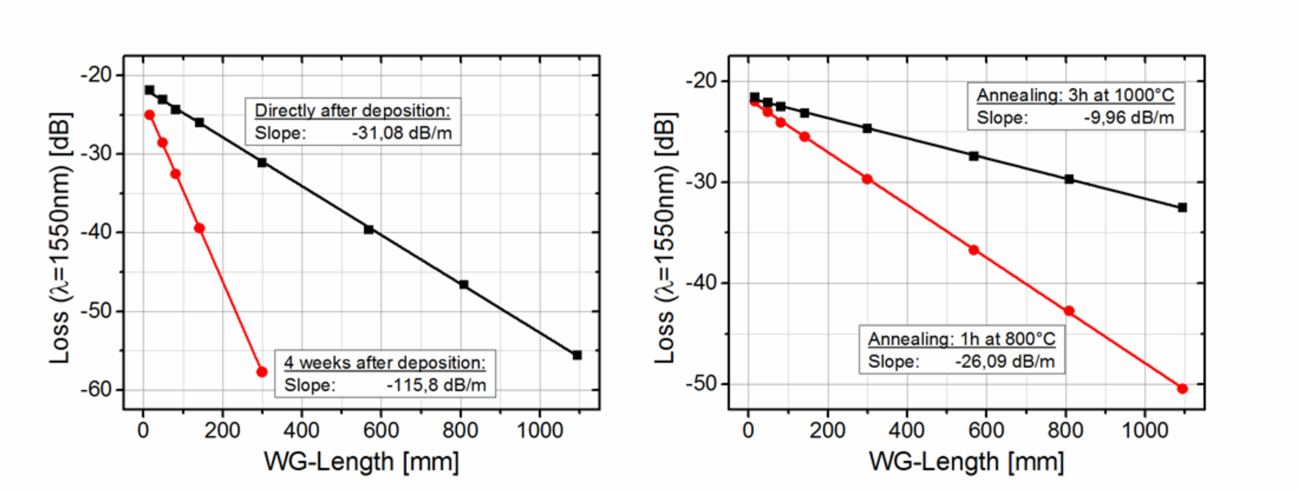


Figure 14: Results of waveguide loss measurements after different annealing processes. Slope of linear fit corresponds to waveguide loss.

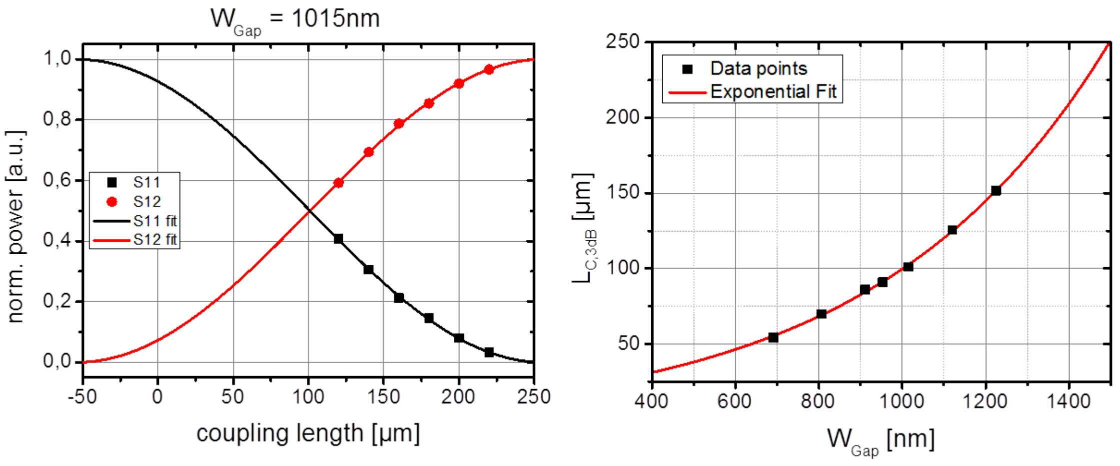


Figure 15: Experimental investigation of power distribution in directional couplers. (left) Exemplary measurement data and sinusoidal fit for a directional coupler with a gap width of 1015nm. (right) Optimal coupling length plotted for different gap widths.

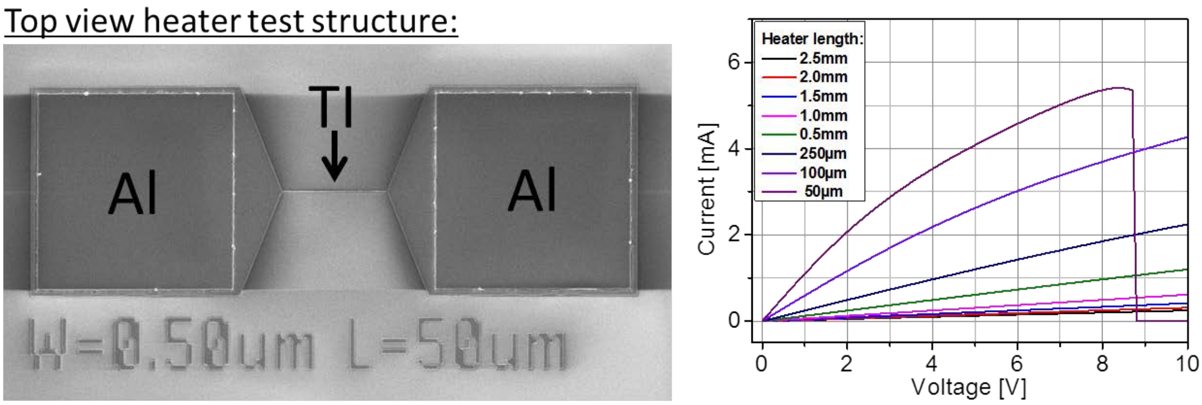


Figure 16: Heater test structure. (left) SEM top view showing thin Ti heater line and thick Al bond pads. (right) I-V characterization displaying heat induced non-linear behaviour and breakdown.

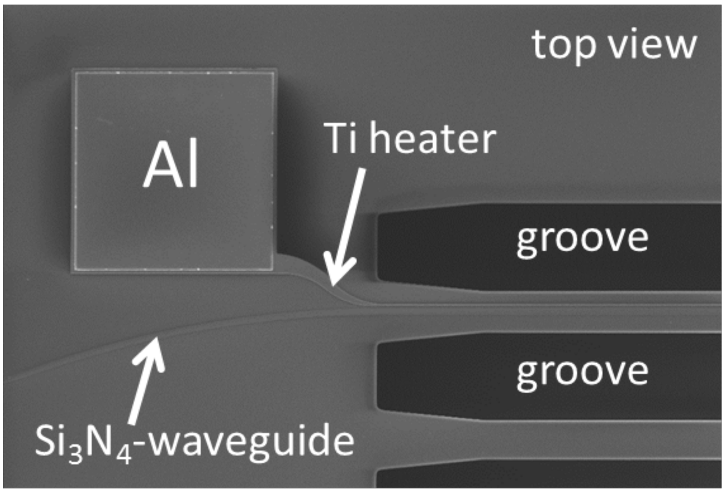


Figure 17: SEM image of a section of a thermo-optic switch

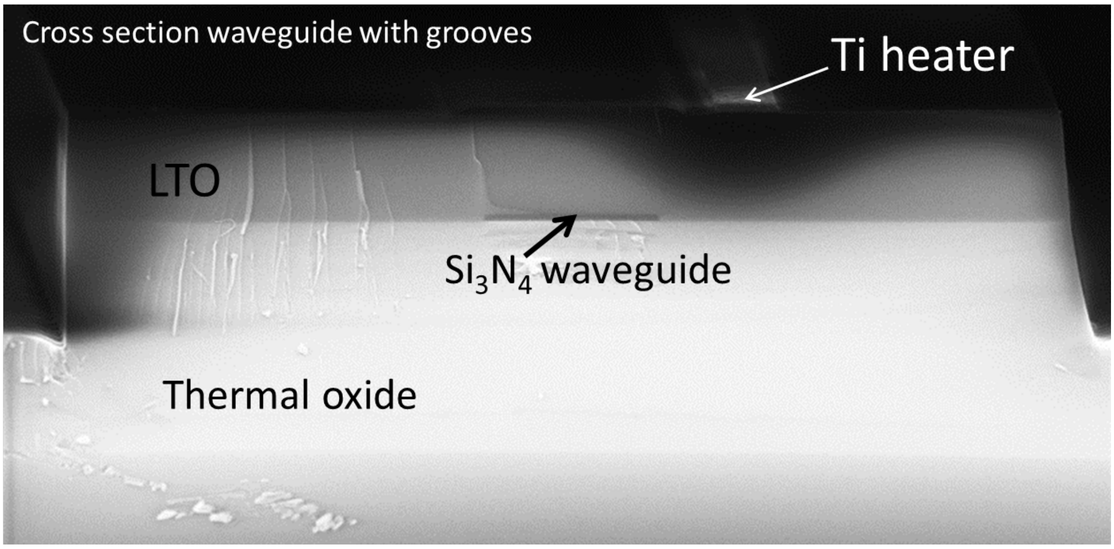


Figure 18: SEM cross section image of one MZI arm of a thermo-optic switch

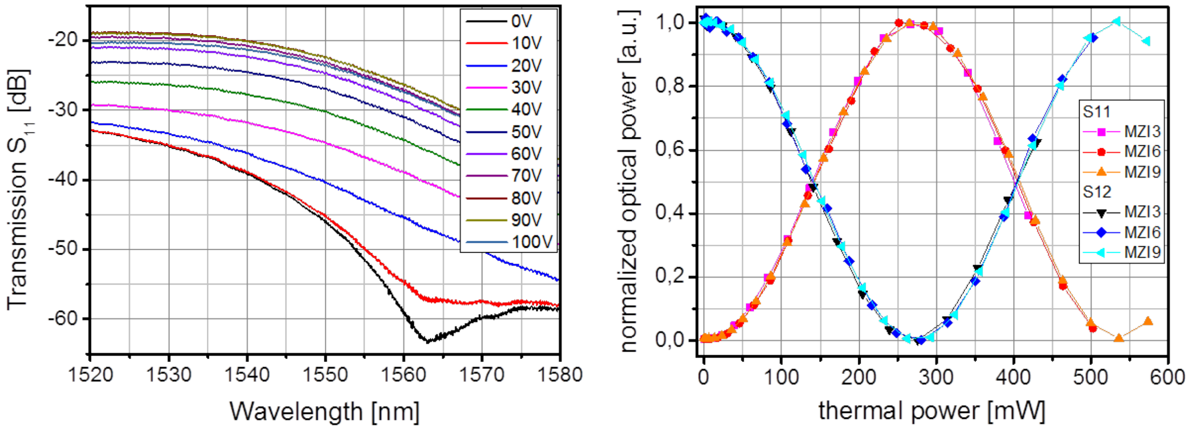
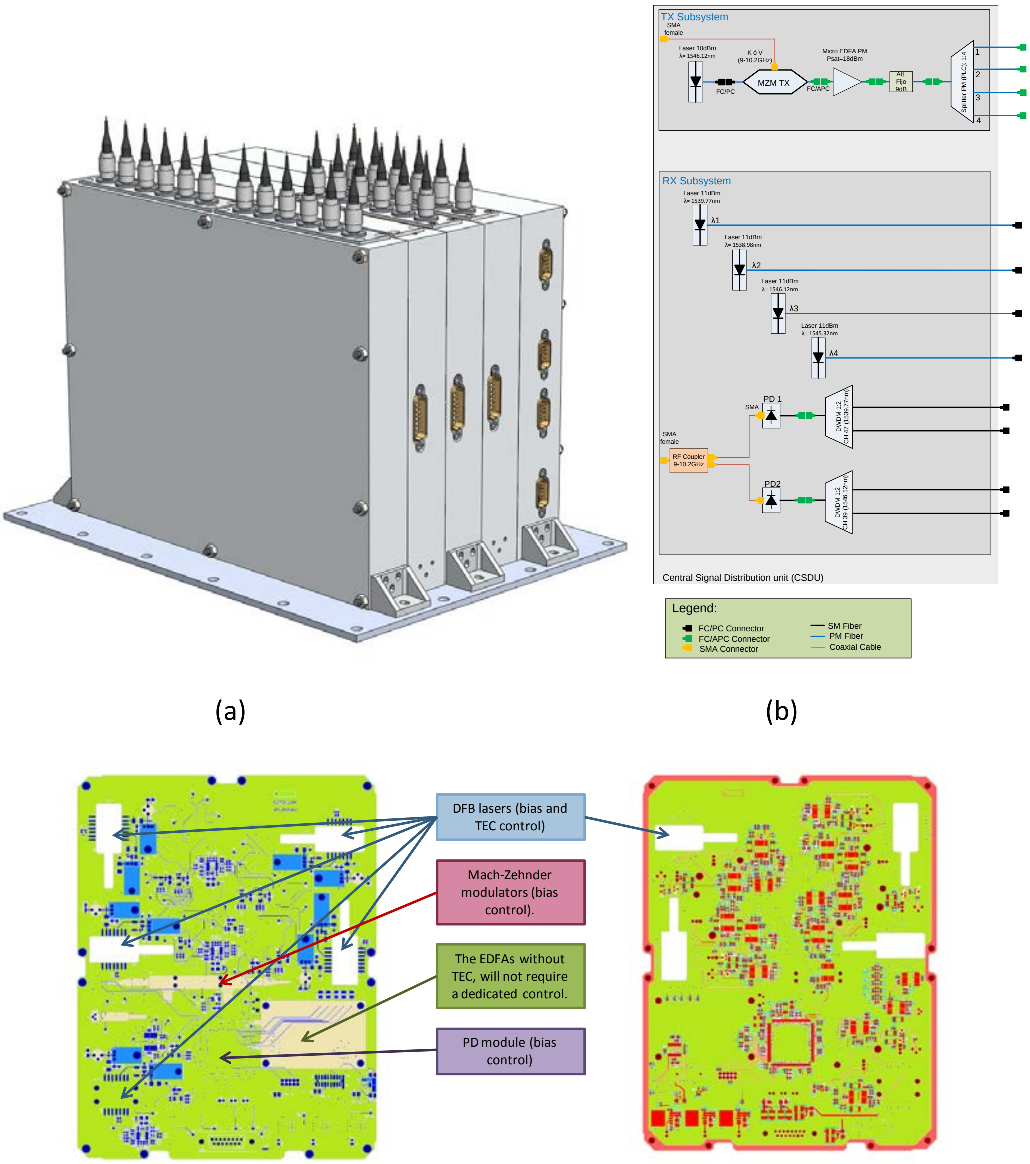


Figure 19: Thermo-optic modulation. (left) Transmission measured on a thermo-optic switch from inport 1 to outport 1 for varying voltages. (right) Normalized optical power plotted over induced thermal power for different thermo-optical switches

During the Third Reporting Period (October 2014 – September 2015) the CSDU E/O conversion module has been concluded and the developed photodiodes and selected components integrated in the final assembly. The design of the control beam was implemented using a USB port with a control computer with a GUI and the possibility of remote control through an Ethernet port.

Similarly, for the APFE, the detailed design of the building blocks (BB) of the PIC (the coupling from/to Fibre-waveguides, the MZI - 3dB couplers with thermal control - and the low loss waveguides connecting these blocks) has been concluded during the this period. Critical performance parameters, such as switch crosstalk, have been carefully assessed through simulations. The ready to manufacture PIC final design was developed. The PIC was defined and packaged. After defining the manufacturing methods and fabricate the different elements, a series of tests (horizontal coupling, pigtailing losses, wire bonding) were performed in order to define the optimum packaging process. In practice, we experienced a lot of problems and several fabrication runs and redesigns (1st and 2nd generation chips) were needed in order to be able to achieve a functional PIC. In parallel, the required PCB and the surrounding mechanics, RF electronics, E/O conversion and control and bias circuits were designed and fabricated to achieve a functional demonstrator.



(a) (b)

(c)

Figure 20: 3D view of the beamformer network (a), schematic of the CDSU (b) and diagram of the manufactured CDSU control board (c)

A 2nd generation photoreceiver with integrated amplifier was designed and fabricated but the delivery was delayed so it could not been included in the system demonstrator.

The AES (antenna) was finally fabricated and once tested was confirmed to provide the required wideband performance. It was also confirmed that the BFN multi-layer configuration avoids coupling effects which degrade the radiation pattern performance in terms of SLL characteristics.

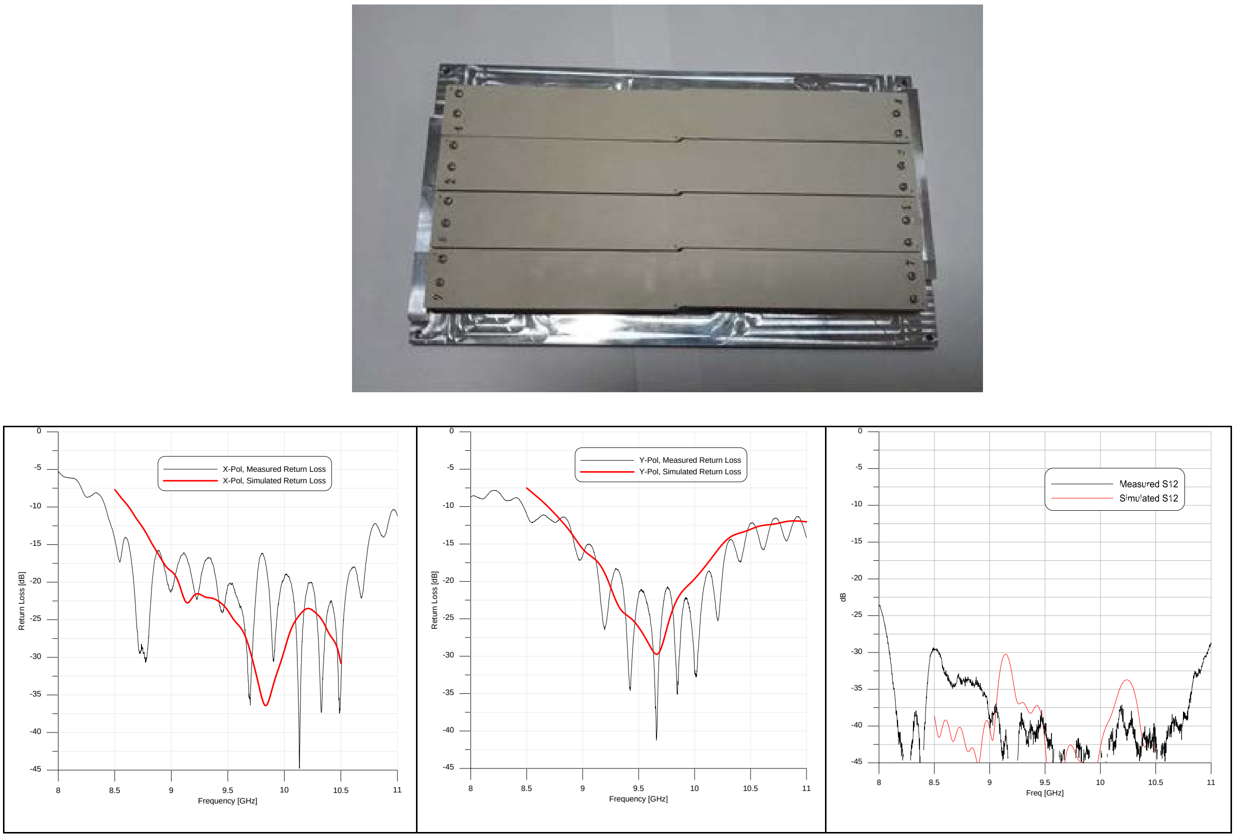


Figure 21: Picture of the AES and measured S-parameters and radiation patterns.

Finally, the OBFN has been integrated and characterised in the lab. The antenna demonstrator has been tested in passive configuration. The radiation pattern has been calculated from the measured delay profiles, showing the expected performance.

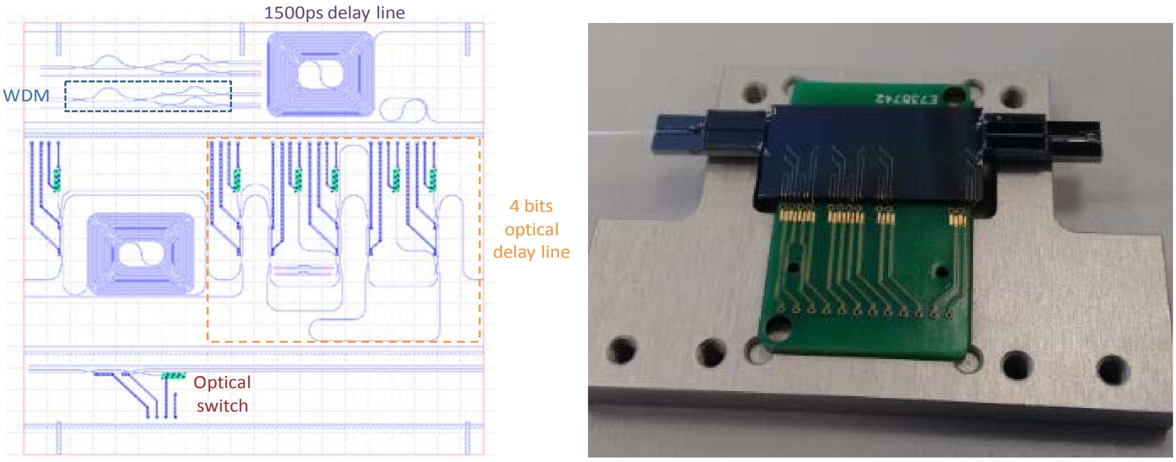


Figure 22: Layout of 2nd generation PIC design and PIC wire-bonded to the PCB with the lensed fibres pigtailied in the package

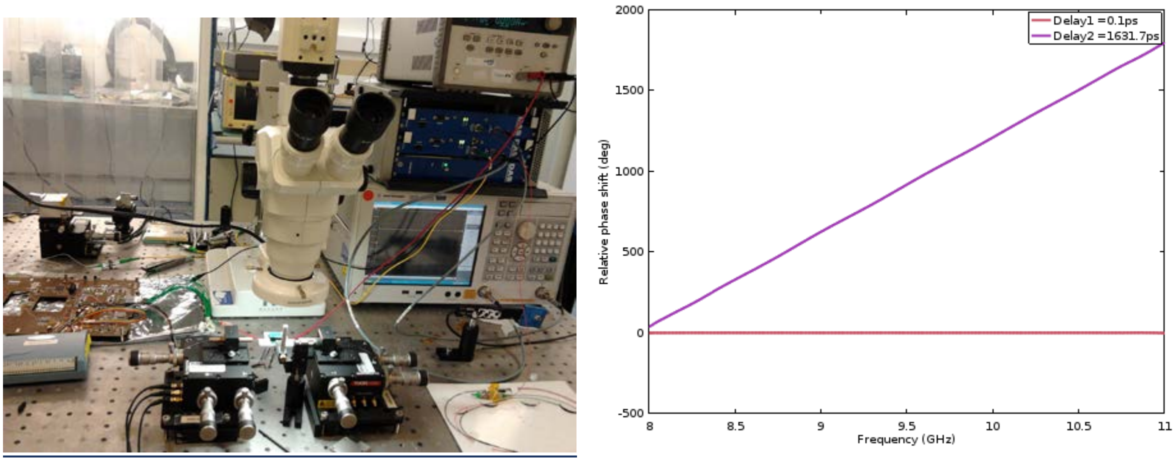


Figure 23: Experimental set-up for PIC characterization and measured true time delay (TTD) achieved by the PIC

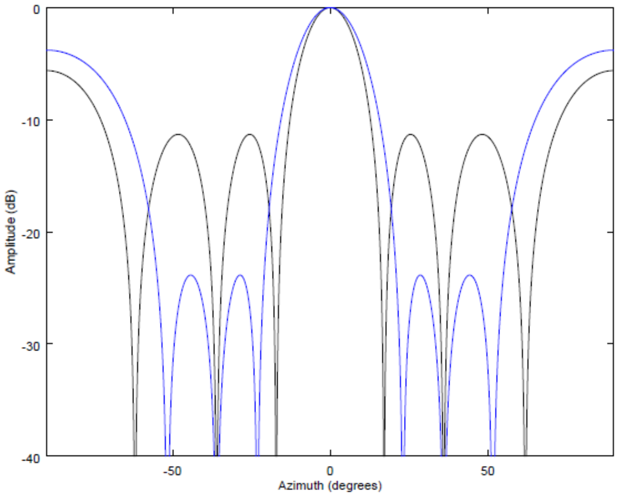


Figure 24: Estimation of the radiation pattern for a uniform (black) and a triangular (blue) distribution of currents on the antenna elements.

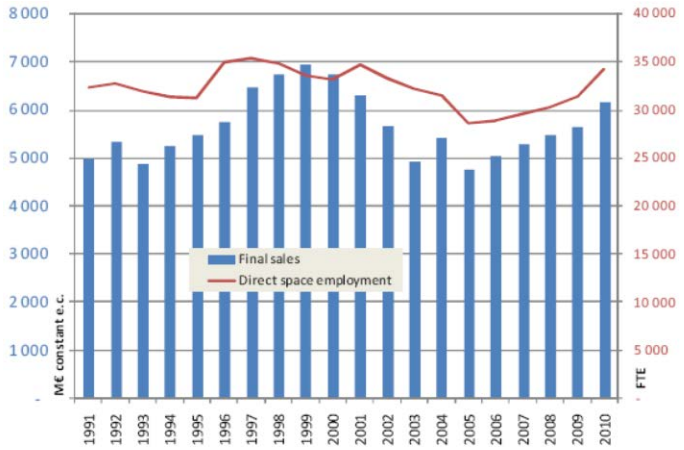
1.4. Potential Impact

Current situation of the EU space manufacturing industry.

The European space manufacturing industry is a potential market of application of GAIA results, however, the flexibility of the proposed technology allows to extend the applicability of the GAIA results to other areas such us, satellite telecommunication, avionics, optical memories, delay equalizer, and communication systems applications.

The European space manufacturing industry, which is a potential market of application of GAIA results, is a niche strategic sector within the wider European Aero-Space and Security industrial complex. This industry is distributed across all Europe and dominated by France, Germany, Italy, where the major industrial sites are located, and, to a lesser extent, UK, Spain and Belgium.

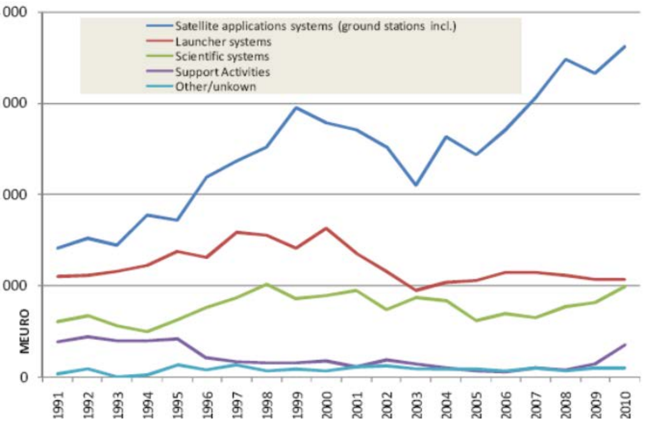
A positive trend in this sector is observed from a study carried out by the association of the European Space Industry (Eurospace) which has evaluate the space industry evolution over the last decades. Figure 25 shows the sales and employment global evolution of the space sector during this period of time in Europe.



Source: Eurospace

Figure 25. Final sales and employment evolution of space industry in Europe.

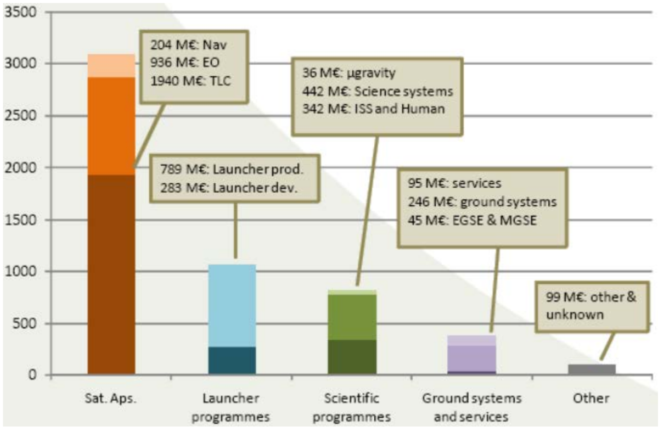
The European space industry is active in all areas of satellite applications, as well as, in launcher and scientific programmes. Historically, the two main areas of development of the industrial space sector in Europe were scientific satellites and launchers. However, due to the gradual maturation of space technologies and systems, satellite applications have become the main source of revenue for the European space industry, as can be seen in Figure 26 extracted from the figures survey. In this sector, satellite application, where there is a tremendous interest in reducing the size and power consumption in order to reduce the cost and to reach new capabilities such as beamforming, large local oscillator generation and distribution or photonic processing. Therefore, it would be of great interest the development of new approaches, such as the photonic front-end in GAIA project, to make this goal possible.



Source: Eurospace

Figure 26. Number of sales by programme type during the last years in Europe.

The core of space manufacturing activity in Europe lies in the design, development and manufacturing of satellites for operational applications (3.1 B€B€ i.e. 50% of final sales), and is the main domain of exports (with 1.13 B€) as seen in Figure 27. The two most important segments in terms of income are telecommunications (far beyond the two other ones) and Earth observation. Within satellite applications, positioning & navigation is the segment with less export sales, it is today limited to institutional customers in Europe.



Source: Eurospace

Figure 27. Sales by programme during the last years in Europe.

Main customers for telecommunications systems are private satellite operators worldwide (1.2 B€) while institutions represent almost 600 M€. The 1.2 B€ commercial sales are evenly distributed between Europe and exports (which include a good share of equipments sold to non European companies). Public satellite operators are the main export customers.

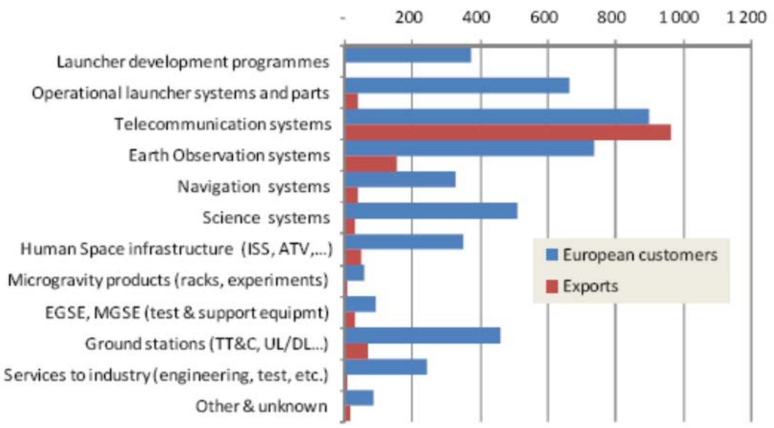


Figure 28. European sales vs exports (M€)

In particular, the satellite telecommunication industry which is, by far, the most important space sector for the European satellite manufacturing industry, representing more than 60% of satellite activities in Europe (Figure 28) will benefit from this project. In both, satellite applications and avionics, low mass, size and power consumption are of vital importance to reduce mission costs and increase operational life in satellites, as well as environmental benefits due to reduction of fuel needed during launch, in satellites, or flight in avionics systems.

Moreover, the European Space Agency points out that the health of the global satellite telecommunications market is evident since, the transponder occupancy of the main satellite operators have improved drastically, causing a rise in new satellite orders (26 in 2006, 20 in 2007 and 25 in 2008). Two thirds of the new capacity was devoted to replace satellites that had reached the end of their operational life. The remaining third constituted growth of existing services and the emergence of new systems.

The EU industry has managed to retain a market share of about 40% of the space segment. However, the technical and commercial pressure from both USA manufacturers and new space powers obliges European industry to maintain a high level of competence and innovation, as that resulted from GAIA results.

In addition to the relatively mature market for fixed and broadcast satellite services, other satellite communications services are evolving very swiftly, besides, mobile satellite services are in constant evolution. Finally in avionics systems, the continued growth of satellite communications services of nowadays stands for the developments of broadband and smart systems that allow the end user to use these services regardless of where they are.

Exploitation and impact of GAIA achievements

Phased Array Antennas have been considered prohibitive for space applications and their applicability has been considered only for particular mission of Earth observation (i.e., Synthetic Aperture Radar SAR).

The drawbacks are mainly related to the great power consumption, due to the low efficiency of the power amplifiers, and to the complexity of the Beam Forming Network, which has the task to distribute the signal and to steer the beam.

Anyway, Phased Array Antennas allow generating multiple beams for satellite communication systems with a high degree of re-configurability and flexibility; so the satellite operators have encouraged the developers to individuate antenna configurations which exhibit characteristics of feasibility.

The main capabilities demanded to the BFN for Phased Array Antennas are the following:

- Fully reconfigurable but not complex BFN: it can be used both in transmission and in reception, also in the case of digital implementation.

- It is not dependant on a specific antenna architecture as it is nowadays (e.g.: possibility to use in direct-radiating or focal array fed reflector): it allows for a modular, scalable and efficient design solution for reconfigurable BFNs capable of supporting various multi-beam configuration.

- It includes a plurality of input and output ports, and includes a plurality of signal dividers, phase and amplitude weighting units, switches and signal combiners to associate each input port to its output port through respective weighting units.

At moment the operative multi-beams phased array antennas for space applications are SPACEWAY3 and WINDS (for telecommunication services), STANTOR (for military services).

Recently, ESA, Eutelsat and Airbus Defence & Space have signed the first contract aimed to design, to manufacture and to lunch the fully reconfigurable QUANTUM satellite, which will represent the most flexible payload ever.

❖ QUANTUM Program

The Quantum programme is a departure from the traditional, custom, one-off approach to building satellites by offering a new and generic payload design. For the first time, it will enable users to request the performance and flexibility they need in terms of coverage, bandwidth, power and frequency.

The satellites developed under the Quantum umbrella will be cheaper and quicker to build compared to current methods by using generic subsystems and equipment, enabling larger-scale production and more efficient control of stock.

Quantum will also be able to completely transform in orbit. Once in space, the chameleon-like satellite can adapt to new commands in coverage, frequency band, power use and even change its orbital position. This will make it the first generation of universal satellites able to serve any region of the world and adjust to new business without the user needing to buy and launch an entirely new satellite.

This ability to mirror or complement another satellite anywhere in geostationary orbit will transform fleet management and result in a significantly more efficient use of resources.

Quantum is a public–private partnership (PPP) between ESA, leading satellite operator Eutelsat and Airbus Defence & Space (UK). The partnership ensures the three parties share risks and funds.

The first Quantum satellite will be delivered in 2018 and operated by Eutelsat to serve government, mobility and data markets.

Figure 29. QUANTUM Satellite

The GAIA project has allowed to advance another step to the development of a reconfigurable beam former which uses the peculiarity of optical technologies.

The objective is to develop suitable configurations able to compete with the classic RF solutions, so much that the OBFN will be a valid substitute.

Optical BFN could find application within phased array antennas in different areas:

- Communications;
- Remote sensing (real and synthetic RF instruments such as radars, radiometers, altimeters, bi-static reflectometry and radio occultation receivers for signals of opportunity missions, etc.…);
- Electronic surveillance and defence systems (e.g.: air Traffic Management and generally moving target indicator radars, RF instruments for interference analysis and geo location);
- Science (multi-beam radio telescopes);
- Satellite navigation systems.

In satellite communication systems, the OBFN could be mainly used for two major classes of coverage:

- For the development of broadcasting and multicasting services (Multiple Contoured Beams) based on linguistic zones consisting of differently sized and shaped geographical regions.
- For point-to-point services (Multiple Spots with cellular like configuration) allowing for higher gains and relaxing user terminals requirements.

In this respect, the OBFN system, providing multi beams capabilities, could represent a valid alternative with respect to current RF solutions exhibiting characteristics highly innovative.

OBFN offers the possibility to integrate in minimized volume several networks for the distribution of the signals associated a different multiple beams; exhibiting power consumption equivalent to the typical BFN configurations working at RF, but with improvement in terms of mass and volume.

Accomplishment of GAIA's objectives by the development of new concepts and technologies for deployable SAR antenna (i.e. complete modular antenna system with photonic integrated true-time-delay) with a net gain in bandwidth/resolution size, mass, complexity and cost when compared with traditional implementations will contribute to the implementation of next generation SAR applications for future Earth observation missions and strengthening the European leading in GMES.

The evolution of future generation of SAR has shown a clear trend towards systems with higher performance resulting on higher complexity (larger antennas, operating bandwidth and/or different frequencies) at lower cost, less mass, size and power consumption. This trend imposes strong requirements in the today's RF and antenna technology since larger antennas means complex, bulky, difficult to route RF harness to transport the signal from/to the beamforming to/from antenna, and strong mechanical and thermal requirements, especially when in-orbit deployable antenna structures are required. On the other hand, larger bandwidths associated with larger antennas and scanning angles requires True-Time-Delay beamforming, resulting in bulky and complex solutions (and very limited for lower frequencies – larger delays) impacting directly in the size, mass and integration cost.

The achievement of GAIA goals will contribute to ***increasing innovative capacity of future developments*** *by addressing* a significant progress beyond the State-of-the-Art in antenna technology for SAR applications, improving the figures of size-mass-cost and achieving the call objective of compact RADAR / SAR technology for future Earth observation missions which will contribute to strength the European leading in GMES.

1.5. Contact details

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