WP1 : Identification of key issues and market request

Architecture and functions

Deliverable 1.1
Final Report
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1 Introduction

This document reports on the analysis of the field of Microwave Optoelectronics and on the Architectures and Functions required for the applications of this technology to the processing of microwave and millimetre wave signals to:

- airborne and spaceborne applications.
- ground based systems and automotive applications
- security systems

and the approach take care of the duality between civil/commercial applications and defense applications.

The document is shared in the following parts.

The first part addresses optoelectronic beam forming architectures and optoelectronic functions linked to the previous applications. A first analysis of the critical technologies and components associated to the optical architectures is presented.

The second part is dealing with an overview of the main applications envisaged for the microwave optoelectronics technologies for security systems.

The third section is devoted to duality between telecommunication and defense systems, especially through the control of broadband or wide band antenna systems.

The fourth section addresses
2 Architectures and functions - Optoelectronics/ Photonics and antenna arrays

In future generation phased arrays, signal distributions will have to fulfill strict performance criteria. These include high isolation from both electromagnetic interference and cross talk between module or sub-array feeds with increased instantaneous bandwidths; dramatic reduction in size and weight regarding present antennas; and performance compatible with growing requirements such as high frequency, low noise and phase noise and high dynamic range.

Optoelectronics and micro/millimeter-wave technologies offer new opportunities for controlling many thousand-array elements together while handling the wide bandwidth of shared aperture antennas. Optoelectronics technologies will provide an interconnect solution for future phased array antennas, which have conformability, bandwidth, EMI immunity, size, and weight requirements which are becoming increasingly difficult, if not impossible, to meet using conventional electrical interconnect methods.

Future system requirements will require high performance wideband analog/digital micro/millimeter-wave links, True Time Delay architectures and combined receivers.

According to this analysis, the main architectures and functions related to optoelectronic and antenna arrays are listed below:

- Optoelectronic beamforming networks
- Optoelectronic processing of microwave signals including filtering and signal analysis, mixing functions
- Generation of microwave/millimeter and sub-millimeter wave signals

These functions analysed in the following document and related to system applications give rise to an analysis of the critical technologies required to implement the functions and architectures, for the future system applications.
Three main steps are identified: current and short term applications up to medium and long term applications.

2.1 Architectures and functions

2.1.1 Current status

One of the present application areas for RF fiber optic links (as opposed to digital links) is the remoting of antennas from the electronics, i.e. the receiver, transmitter, controls, user interface, etc. Examples of antenna remoting can currently be found in both the commercial and defense markets. RF optoelectronic links are being used to convey signals between base stations and cellular antennas as well as between the receiver and antennas of advanced radars.

Important as these initial applications are in establishing the credibility of this new technology, they are really just the first step along a path that eventually could lead to the evolutionary merging of two fields: optoelectronics and antennas. However in these present applications, the optoelectronics are basically replacing conventional components, such as the coax that would have interconnected the antenna and electronics.

In the replacement stage, the design of the electronics is largely, if not completely, unaffected by the optoelectronics. Although the RF optoelectronic link provided advantages, such as increased immunity to EMI and the ability to increase the distance between the antenna and the electronics, the RF optoelectronics did not change the system in the sense that no new capabilities were introduced.

2.1.2 Medium term evolution

A second step in the evolution, which we are beginning to see signs of already, is the integration of optoelectronics with antennas. In this stage the system design treats the optoelectronics and electronics as two complementary technologies that can be blended together to obtain performance that was not previously possible from either technology alone.
It is important to note that the term “integration” is being used here to refer to both physical as well as functional integration of the two technologies.

As an example, a contract entitled OBANET (IST – 2000 – 25390) ‘Optically Beam-formed antennas for adaptive broadband fixed and mobile wireless access NETworks is devoted to the analysis and sizing of beam forming architectures to perform multi-beam applications in a frequency range around 40 GHz. Optics and optoelectronic technologies are involved for the realization of True Time Delay (TTD) architectures required for multiband or broadband applications.

An example of physical integration would be designing the filter, LNA and diode laser as one sub-assembly and locating them on the same substrate. An example of functional integration would be a frequency conversion optoelectronic link that can replace the first stage of down conversion in an RF heterodyne receiver. By conveying a lower frequency IF over the optoelectronic link, it is possible to remote 60 GHz antennas over 10’s of kilometers of distance. A defining feature of this stage is that it introduces new capabilities that were not possible in stage one.
2.1.3 Long term applications

2.1.3.1 Photonic antenna

The third step in the evolution is a photonic antenna.

In this stage the optoelectronics performs the sensing of the electro-magnetic field, thereby replacing conventional antennas. One or two examples of antenna designs along this direction have been reported at the Photonic Systems for Antenna Applications (PSAA) conference. At this stage, entirely new types of antennas would be possible, since optoelectronics would permit sensing as well as remoting the RF field without any electrically conductive elements to interfere with the antenna pattern.[Charles H. Cox MIT "step Towards Photonic Antennas"].

This function could be applied to security systems as discussed in the paragraph 3.

2.1.3.2 Micro/millimeter-waves

The intrinsic features of fibers (extremely low losses: 0.2 dB/km) allow preserving propagating signals along kilometers. However conversion losses between electrical and optical information cancel the fiber advantages, especially when large frequency bands are addressed. That currently leads to more than 30 dB of loss at transducer interfaces and limits the application domains such as analog micro/millimeter-wave transportation.
2.2 Optical beam forming network

The key trends in spacecraft antenna technology are toward larger effective apertures, significantly higher numbers of beams, and integrating computationally-intensive beam forming and switching activities with other onboard processing functions.

Optics offers the potential for volume, mass, and power reductions with increased speed relative to similar subsystems implemented using electronics.

2.2.1 Optoelectronic beamforming architectures for broadband system applications.

2.2.1.1 Review of Optical beamforming networks architectures

As pointed out True Time Delay (TTD) beamforming is required when wide band operation is combined with significant beam steering offset. In this case there is a need of low loss transmission links allowing the remote control of the antennas and the distribution of large bandwidth microwave signals. This need is fulfilled today by microwave optical links, owing to an increase in the modulation bandwidth and the dynamic range of optical emitters and detectors. Furthermore, optoelectronic architectures, because of their inherent parallel processing capabilities, bring attractive perspectives for radar signal control and processing.

According to these considerations, a large number of Optical Beamforming Networks (OBFN) have been proposed during the last decade. One can classify these architectures according to five generic approaches:

- switched delay lines
- laser/photodiode switching
- wavelength coded architecture: dispersive delays/Bragg grating delays
- 2D optical delay lines.
- coherent OBFN

For each approach we will detail in the following a typical demonstration that already includes a built array. This overview is completed with related published references and a description at the work, performed in this field, by each partner.
Identification of critical aspects for each architecture and related applications

2.2.1.2 Major critical aspects

In the following, We summarize some critical aspects for each generic architecture.

The major critical aspects of the TTD architectures are related to:

- phase noise of the light source for the distribution of local oscillator or for the distribution of RF signals
- linearity and dynamic range of the optoelectronic components to fulfill the requirements of radar signals (Receive mode)
- additional phase noise contribution due to optical switching
- degradation in the dynamic range due to additional losses induced by the TTD architecture
- phase error induced by error on the time delay control
- phase error induced by cross-talk in the optical switches

**Switched delay line**

- Influence of the 1->N distribution and of optical amplification on the high stability or the phase noise of local oscillator and signal.
- Optical switching influence on signal to noise ratio.
- Sensitivity to environment: except in the case of a solid state integration of all the delays (only for small antennas using integrated optics technics), the use of separated delay lines (i.e different path), increases sensitivity to environment, especially in terms of relative phase stability of the signals.

**Dispersive fiber**

The present a thermal stability problem related to the use of large fiber lengths. The refractive index thermal slope is the main contribution to the thermally-induced time delay variations which accounts for most delay errors and calibration stability problems.
extension of this concept up to 256 T/R modules is related to the use of optical amplification in an Er doped fiber amplifier. But in this case the tunable range is limited to 30 nm and will require a high wavelength resolution (~0.05 nm). This last one will reduce the microwave frequency of the system (0.8 nm ~ 100 GHz) and will increase its sensibility to environment.

Extension to 2D scanning. (In order to control a 8x8 array it is then necessary to implement 9 (1+8) "prisms").

The advantage of this approach is mainly that it only requires N+1 driving signals (one for the control of each wavelength) for a NxN array. Conversely the main limitation seems to; sensitivity to environment since precision on time delay is directly related to the stability of the laser wavelength. According to these considerations it seems realistic to reduced number of T/R modules (8x8) with a quite small number of bits (~6) of delays.

Bragg grating

- it requires a tunable laser + a modulator for each T/R module or subarray. At this time, maturity of tunable semiconductor lasers is not sufficient to provide low cost components.

- performances of the optical circulators with very high frequency microwave signals has to be checked, mainly in terms of possible signal distorsion.

- performances of Bragg filters in terms of

  - insertion loss : when a delay line is tuned to \( \lambda_R \), what is the contribution of the \( \lambda_j \) to the noise floor at the link (same consideration of the cross-talk in any other architecture).

  - selectivity / reflectivity / phase precision : a good wavelength selectivity is provided with long gratings. Conversely a good time (or phase) precision is obtained with
short gratings (short in comparison with the microwave wavelength). According to
the operating frequency, this trade-off has to be optimized.

- possible sensitivity to environment.

**Free space 2D**

- according to the parallelism of this approach, the volume and complexity of the hardware
are not directly related to the number of channels processed.

- due to the corresponding reduction of the pixel size, diffraction becomes a major problem
that requires, in order to maintain a low cross-talk level, imaging of each SLM onto the
following one.

**1xN**

- Distribution of a local oscillator for receive mode.

- Influence of the switches on the carrier to noise ratio

- Sensitivity to environment: necessary solid state integration. One can notice, furthermore,
that all the channels travel in the same structure. Most of the fluctuations of the pathlengths
will affect all the channels at the same time and thus will not modify the relative phases of the
distributed microwave signals.

- This architecture requires highly polarized laser beams in order to preserve extinction ratio.
Fluctuation of the light polarization, in presence of optical amplification, appears to be the
main limitation.

**NxN**

In addition of the previous critical aspects:
Relaxation of the power level demand.
Since such an architecture is able to process the receive mode, noise figure of the delay line
becomes a major specification.
2.3 **Optoelectronic processing of microwave signals including filtering and signal analysis, mixing functions**

One of the fields in which microwave photonics can substantially contribute to outperform the features of currently available RF and microwave components is in the area of RF and microwave filtering. Traditional RF filters are static, difficult to tune and reconfigure and lossy. The use of photonic components to build up filters capable of processing RF signals directly in the optical domain opens the possibility for the implementation, either in waveguide or in free-space format, of flexible, tunable, reconfigurable and high Q RF filters. This area has been the subject of active research for at least the last 15 years. However it has only been recently that novel proposals have been made that can lead to filters that truly can attain impressive figures such as tunability range in excess of 60 GHz, transfer function reconfiguration at speeds below 1 \( \mu \text{sec} \), and Q values above 1000.

A project entitled LABELS is underway with common partners as NEFERTITI.

**Microwave guided wave signal processing** and filtering employing passive and active optical components is one of the most promising possibilities brought by Microwave Photonics (MP). Several works have been addressed this area, employing different strategies and solving different limitations of such filters but leaving others without solution at the same time.

The main expected features of the future guided wave MP filters that we will deal with, are:

- Great frequency range of operation (Tunability range > 60 GHz).
- Fast tuneability and reconfigurability. Either by steps or in a continuos way.
- High Q factor filters requiring a high number of filter coefficients (>50).
- The possibility of negative coefficients, and the possibility of amplitude adjustment of these (or windowing).

The implementation of complex filtering shapes will be analysed, including not only low pass filters but high pass filters, or the synthesis of high decaying slopes (high roll-off) with quasi flat band pass, requiring the use of **Negative Coefficients** (approaches as the differential detection or the use of **Semiconductor Optical Amplifiers (SOA)**, for the sign inversion of the negative coefficients by Cross Gain Modulation (XGM)).
2.4 Generation of microwave/millimeter and sub-millimeter wave signals

Optical generation of high spectral purity signals in the GHz up to the THz range is a major challenge of the coming years.

The extremely high frequency imaging systems devoted to security aspects for example, will require to generate low phase noise signals to be able to perform high quality images or high sensitivity detection functions.

As a topic unabling the junction between the RF field and the IR field, optoelectronic technology appears as well adapted to these functions.

Approaches such as dual frequency sources or quantum cascaded sources or OPLL based sources need to be developed to achieve the envisaged goals.
3 Applications to micro/millimeter wave systems

For the applications of microwave optoelectronics technologies to system applications, the Thales approach is based on the duality of the technology for civil and defense system applications associated with the communalities of the broadband wireless system approach and the wideband system requirement for the next generation multifunction systems.

The different fields of envisaged applications of the microwave optoelectronic technologies is described in the following paragraphs. It concerns:

Aerospace applications
- Satellite based radar and communications systems
- Broadband multimedia services

Imaging and security systems
- Security systems
- Autonomous landing systems
- Automotive applications
- Air traffic management radar systems

Duality Telecommunication/Defense systems
- Terrestrial base station wireless antennas
- Defense systems: wideband multifunction systems

Table 1 illustrates the communalities between civil and defense applications including security aspects. These applications have been splitted into three main areas:
- Radar systems;
- Beam forming networks (BFN) with narrowband multi-beam capabilities;
- Multifunction systems able to process wideband analogue or/and digital signals.
As it can be seen in this table, aerospace applications address all Thales areas of interest for dual use applications while for security and imaging systems only radar systems and narrowband BFN are addressed.

<table>
<thead>
<tr>
<th>Space applications</th>
<th>Defense Civil</th>
<th>Radar systems</th>
<th>Beam Forming Networks (multibeam -narrowband)</th>
<th>Multifunction Systems (wideband)</th>
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<tbody>
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<td>Satellite based radar and communication systems</td>
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<td>Broadband multimedia services</td>
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<td>Security systems</td>
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<td>Air traffic management radar systems</td>
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Table 1: Civil / Defense application duality.

### 3.1 Focused Application Areas

#### 3.1.1 Aerospace (spaceborne applications)

The introduction of optoelectronics in the space environment involve a full compatibility with space environmental constraints. These constraints are mainly the capacity to operate at low temperatures, to be able to survive the harsh deep space environment, and the compactness of the devices. Several experiments and projects have addressed the study of radiation damage of optoelectronic components in space, and today space qualified optoelectronic products start to be available for data transmission for rates higher than 2.5Gb/s. Future steps will be the
development of analogue fiber optic links and related components for signal processing, compatible with the space environment.

Optical processing can provide improved performance and efficiency when implemented in a satellite.

It can be used mainly in three places in a communications satellite:

- Intermediate Frequency (IF) and radio frequency (RF) communications signal switching and distribution;
- Phased array antenna control and beam forming with many independently steerable beams require a large number of radiating elements with individual phase (and amplitude) control for each beam;
- Baseband processing and switching involves functions similar to those performed in terrestrial local area networks and telephone switches. In addition, demodulation, demultiplexing, error detection and correction, switching, congestion control and notification, buffering, remultiplexing, and modulation and network synchronization must be performed.

3.1.1.1 Satellite based radar and communications systems

Emerging telecom satellite system requirements encourage reconsidering the respective role of the ground and the satellite segments. The increasing number of users accessing simultaneously to the satellite the demand for higher bandwidth per user the need for simplifying the user terminal, the need for global connectivity and network reconfigurability are as many drivers that now shift the complexity towards the satellite. Future telecom satellite payloads will have to perform new functions.

These new requirements call for the migration to new payload architectures as well as for the introduction of new techniques and technologies. These new generations of antennas and repeaters that together constitute a telecom payload are also reviewed in the following sections.
There is now a widely shared perception of the role of the satellite segment, in building the global telecommunication infrastructure that should bring the opportunities of the Information society to many parts of the world. Telecom satellite systems are to complement rather than to compete with the ground networks. In this respect, the main differentiating advantages of satellite systems are:

- to provide wide-band direct access to/from the backbone;
- to establish short-cuts between backbone edge sites;
- to extend the Earth network in sparsely populated areas, in countries under development, in regions difficult to reach during deployment phase of ground networks, etc.

### 3.1.1.2 Optical fibre optics sensors

Optical fibre sensing has been particularly approached by the use of Microwave optoelectronics for performing microwave phase measurement. Another field can be addressed by photonic, sensing application applied to damage detection. Optical fibres integrated in the structure can play the role of a damage sensor. By integrating optical fibre in the structure, thus creating a mesh, it is possible to have an estimation of damages size and location on the satellite.

### 3.1.1.3 Communication links

Space-based, free-space optical communications is a concept that has been introduced several years ago. In the last few years, however, there has been several study and demonstrations of free space optical links compatible with aerospace applications. The market for space-based optical communications is mainly for intersatellite links, but there is also a need for high data rate (many Gb/s) for space-earth links, this is illustrated Figure1. Unfortunately, because of the propagation effects through the atmosphere and because of weather this a much more difficult link to realise. Intersatellite communications is used primarily to realise a network with a constellation of satellites at data rates up to many Gbps or for data relay purposes from tens of Mbps up to Gbps.
Free space optical links are interested since optical system has a much narrower beamwidth than a rf system. A narrower beam means interference to or from other satellites will be reduced, but in counterpart requirements are very stringent for pointing the beam. Beside the beam pointing, for space to earth link, atmospheric effects must be taken into account. The use of adaptive optics, can help to solve the effect due to propagation into the atmosphere.

### 3.1.2 Automotive area

In most vehicles today, data communication is limited to diagnostic functions and non-time-critical data transfers. This trend, however, is changing. With drivers spending an ever-increasing amount of time in their vehicles, they are starting to demand the same comforts in their cars that they enjoy in their homes (e.g., high quality sound systems, internet access, multiple playback devices, video displays to entertain children on long trips). As a result, many opto electronic modules (OEM) are beginning to introduce such features in vehicles as digital audio and video that require high data transmission rates (1Mbps - 10Mbps).

With increasingly more functions being added to the vehicle, packaging and wiring constraints demand that these features share resources. From a system integration viewpoint, it is often advantageous to connect all these functions on a single multimedia network.

**Figure 1:** Intersatellite and space earth free space.
operating at data rates up to 100Mbps for short term. At this data rate, traditional vehicle communications media, such as twisted pair, fail to meet functional or vehicle electromagnetic compatibility requirements (EMC).

Optoelectronic interconnects with optical fibers can provide significant advantages in cost, weight, and EMI over existing copper wire harnesses. Many applications of fiber optics use single or multimode glass fibers with a core thickness ranging from 3 µm (single mode) to 50–62.5 µm (multimode) and a numerical aperture less than 0.2.

Whereas the choice for network media may be obvious, the selection of the most appropriate network architecture is not as clear. An optical network can be created using many different configurations: single unidirectional ring, double bi-directional ring, passive star, active star, tree and hybrid combinations of these structures. The vehicle system designer selects a communication architecture by evaluating the system’s functional requirements. Requirements usually considered are: fault tolerance, number of nodes, latency, total system cost, and impact on vehicle buildability. For instance to lower the attenuation due to temperature, different types of fibers must be used for passenger and engine compartment applications, since the temperature varies between -40 to 125 °C for the engine compartment and between –40 to 85°C for passenger compartments.

As it has been presented in the following paragraphs, fiber optic can be used in replacement of the well known copper wires, in order to realise a fiber optic network in the car that allow to deliver several medias or datas. But fiber optic can also be used as sensor to monitor locally several part of the engine compartment or the engine itself. Two types of sensors can be realised with fiber optic, either intrinsic or extrinsic sensors. Extrinsic sensor means the fiber is only used to deliver the light to the sensor that is not the fiber itself, but that is external to the fiber (an external Fabry Perot cavity for instance). While for intrinsic sensor, the fiber media is used as a sensor (for instance, the temperature modify the reflective wavelength of a fiber Bragg grating). In both cases, several sensors can be put in a network and addressed separately. Once again, the network can be created using many different configurations: unidirectional or bi-directional ring, star, ladder, tree or hybrid combinations of these structures.
3.2 Security applications

3.2.1 Security systems

Technologies developed inside Thales for the radar systems in the microwave and millimetre frequency domain are also developed for other civil applications such as automotive applications such as automatic cruise control for cars or trucks.

The use of the technology for imaging systems for security applications for the microwave frequency domain to the sub-millimeter wave technologies is deeply analysed inside Thales for:

- Detecting and imaging objects carried by people for the security in public places such as airports, courthouses,…
- Large events such as Olympic games,… require a large coverage for the security of the events including ground based, air to ground surveillance and satellite surveillance systems based on imaging systems.

The development and demonstration of terahertz sources and detectors for operation in the range between 0.1 THz to 30 THz (0.3 millimeter to 10 micrometer) has received increased interests and attention for several types of applications. The areas which can be addressed by such THz sources include not only space-based communications, atmospheric sensing, short-range communications, near object analysis, but also chemical and biological sensing. Terahertz waves are electromagnetic waves that lie between the infrared and microwave parts of the spectrum. What makes these waves so fascinating is their ability to penetrate materials that are usually opaque to both visible and infrared radiation (for instance, THz waves can pass through fog, plastic, wood, ceramics and even a few centimetres of brick, unfortunately, they can be blocked by a metal object or a thin layer of water).

The list of potential customers for the terahertz wave technology is growing all the time. Military people wants imagers that are able to "see through" bad weather; while chemists want spectroscopy equipment for analysing the structure of new drugs; and airports arguably need better security-screening equipment. As a result, today research is fast evolving, and several equipment will be realised in a close future to address the mentioned above applications.
Exploring terahertz technologies for the mentioned above areas of application requires the development and demonstration of compact THz sources and detectors. In addition to the possibilities of advancing from and upconverting of the millimetre-wave sources and technologies to achieve THz, another approach by which the improvements may be achieved is optoelectronics. It requires the development of unique optical devices, special laser sources, integrated optical-electronic components, improved materials, and the nano-scale structures required to realise these devices. As an example several solutions can be implemented to generate THz waves with optical components:

- The waves can be generated by illuminating a piece of semiconductor (GaAs for instance), with femtosecond pulses from a solid-state laser such as a Ti:sapphire laser. This approach works well and while femtosecond lasers are getting smaller and cheaper, it is still a relatively bulky and expensive solution.

- The waves can also be generated with quantum-cascade lasers, which emit in the mid-infrared around 4 µm. Semiconductor scientists are now adapting the technology to design lasers that are operational in the far-infrared and terahertz regions. Several series of quantum cascade lasers that operate in pulsed and continuous-wave mode at several THz have been demonstrated. Although the lasers can only currently work at low temperatures of up to 50 K, they emit up to 2 mW of singlemode terahertz radiation. The challenge is now to develop new quantum cascade lasers that are working at room temperature.

3.2.2 Network Security

3.2.2.1 Free space optical transmission

Since the development of the internet network, network security is one of the major concerns for any organization transporting sensitive and/or confidential information over the network. Today, most of the interception activity occurs through software layers. Password protection
or data encryption are used as counter measures to protect the network from unwanted intrusion.

However, intrusion can come from the physical layer. This can be a threat if information is transported over a copper-based infrastructure that can be easily intercepted. As an alternative, free-space optics transmission is among the most secure connectivity solutions, regarding network interception of the actual physical layer.

The systems based on this technique can send and receive data through the air between remote networking locations. Their wavelength range is around 1 micrometer and is already in fiber-optic transmission systems. As systems based on this technique can use very narrow beams (less than 1 degrees), the interception of the beam is very difficult since it is necessary to know the exact location of both the emitted and received beams, and to intercept the beam without adding perturbation to the transmitted information.

Several systems based on free space optical transmission have been deployed all around the world. While the bandwidth is not today an issue, due to the increasing demand in high security communication system, the bandwidth and the capacity to multiplex analogue and digital signals will increase in the future.

3.2.2.2 Data transmission security through quantum cryptography

As is has been presented in the previous paragraph, secure data transmission is a field of increasing interest today. Unfortunately, the interception of the transmitted data remains always possible. In order to protect against unwanted interception, encryption processes have been implemented with different levels of success.

Recently, physicists have put the finishing touches on a method of encrypting messages that is more secure than anything that has gone before. This method has the potential to be absolutely unbreakable. This method is based on encryption using quantum physics, and on transmission using fiber optic. One of the main characteristics of quantum cryptography is that it solves the problem of the key distribution, as it was necessary with other methods. Sending a message using photons is straightforward since one of their quantum properties,
polarization, can be used to represent a 0 or a 1. Each photon therefore carries one bit of quantum information.

Using fiber optics provides a secure data transmission, since fiber optic cables do not radiate any signal which may be received by unauthorised parties, as it is the case with copper-based cables. This technology allows easy detection of tapping since if a fiber is bent to tap the light, the attenuation of the fiber will be changed, then the detected signal will be affected by the increase of losses.

This technique is limited to the transmission of digital data at relatively low rates (several 10Mb/s) up to roughly a hundred of km. In the future, higher rates will be addressed (several Gb/s), and transmission distance will also increased. A natural field of this technique is the high security transmission of data through free space optical links.

3.2.2.3 Enhanced Vision radar systems (EVS)

Millimeter wave imaging systems are envisaged for the realization of Autonomous landing radar system. This field usually referred as Enhanced Vision systems is particularly linked to security of airborne platforms for the landing in adverse environmental conditions such as fog or bad weather.

W-band millimetre wave radar systems in the range of 100 GHz will be able to perform some ‘imaging function’ sufficient to identify the landing free way for airport which are not equipped with ground based air traffic control management systems (a large majority of the airport in the world).

Microwave optoelectronics processing in this case could be used to perform the correlation between stored digital images of the airport free way for example and ‘millimeter wave images’ performed by the radar installed in the airplane. Microwave optoelectronic processing and multiwavelength optical memories are envisaged to overcome the limitations of electronic processing for the realization of extremely high number of correlation required by the systems.
3.2.3 Duality Broadband Telecommunication and Defense systems: wideband multifunction systems

This chapter addresses the duality between broadband system network and wideband multifunction systems.

As represented in the generic scheme Figure 2 below, telecommunication systems and phased array radar are quite similar systems which require to distribute signals or waveform generation from a central station (or a synthesizer) to antenna elements or arrays co-located or not co-located.

![Figure 2: Duality broadband telecommunication and defense systems](image-url)
3.2.3.1 Terrestrial base station wireless antennas & Broadband multimedia services

Another example of such a system is represented below and referred as Integrated hybrid fiber radio for pico-cell access and distribution systems.

The figure above show the requirements for the simultaneous emission of signals to the different ‘customer’ static or mobile.

3.2.4 Wideband multifunction systems

Future defense systems will require advanced performances in terms of bandwidth coverage, several decades, antenna beamforming functions for multibeam multiband functions.

Telecommunication market:
No one disputes the success of optical networking in the long haul business anymore and optical solutions for the metropolitan network are starting to take shape. The next frontier is
the access network where new solutions are needed to bring the vast bandwidth now available in the transport network to the end user in an economical and flexible way that enhances existing applications and allows new service offerings. Emerging optical access technologies are poised to enable these solutions, but a low cost optical to electrical receiver will be required.
4 Critical technologies

A preliminary list of critical components and technologies for the foreseen wideband systems is addressed below.

Future (10 Years) optoelectronic devices will have to meet stringent requirements for high capacity optical communications/networking and high frequency analog transmissions. Long term inter-disciplinary research will play a critical role to achieve these goals, and the main key blocks that must be developed are listed below:

- Advanced optoelectronic components for high performance analogue signal distribution;
- Optoelectronic oscillators;
- Multiwavelength up/down conversion devices;
- Optoelectronic components for high speed switching;
- Integrated technologies for the realisation of integrated delay lines;
- Optoelectronic MMICs;
- Optical interfaces compliant with severe environment;
- Optoelectronic processing of microwave signals.

This will probably need the exploration of new materials including polymers and related organic materials, to achieve this goal.