Future Optical Network Architecture for Phased Array Antenna

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Abstract

This white paper describes the D-Lightsys vision for optical network based next generation active antennas and radars. Full optical network architecture, from the processing board up to the antenna Transmitter/Receiver Modules (TR modules) and down to the display and control station, is presented accordingly to the wide offer of D-Lightsys high performances optical modules.

Introduction

Active antenna enables new radar architectures by increasing modularity, reliability and improving beam forming and multiple targets tracking, but the reverse of the medal is that the bandwidth demands increase in consequence. Optical interconnect solutions are very promising to solve the bandwidth, performance, cost, weight and scalability compromise. Thanks to D-Lightsys high performances optical interconnect solutions with the world smallest power consumption by bit rate and by mm^2, Electrical to Optical (E/O)conversion can find advantages and places everywhere in the radar system. This paper doesn't intend to reveal any specify radar architecture, it presents a generic active antenna radar architecture and describes where optical interconnects can find a place and details their main advantages.

Radar and Active Antenna Architecture

Electronic integration and performances increased has change the classical way to design radars: single rotary large reflector antennas have been replaced by multiple elementary phased controlled radiating elements. Phased array antenna allows the design of more compact multiple mission radars.

Phased array radar architecture are mainly constructed around three mains parts:

- *The active radiating elements*: generally composed of several transmitter/receiver sub-system (TR Module) interconnected in a matrix way. Each of the TR module is responsible to generate/receive the electromagnetic field with a specific phase.
- *The computing equipment*: this element, controls the overall phase plan of the field to be generated by controlling each TR modules phase, it treats the received signals from the TR module and is responsible for the beam forming processing.
- *The control and displays*: this part is the interface to the radar operator. The decoded information is displayed and the main system parameters are controlled and operated.

Each of the previous elements could be integrated together into a complete system such in a fighter aircraft or separated by several meters like in field or radar operated missiles battery (fig.1), or eventually by kilometers for communication spy or counter measure systems.

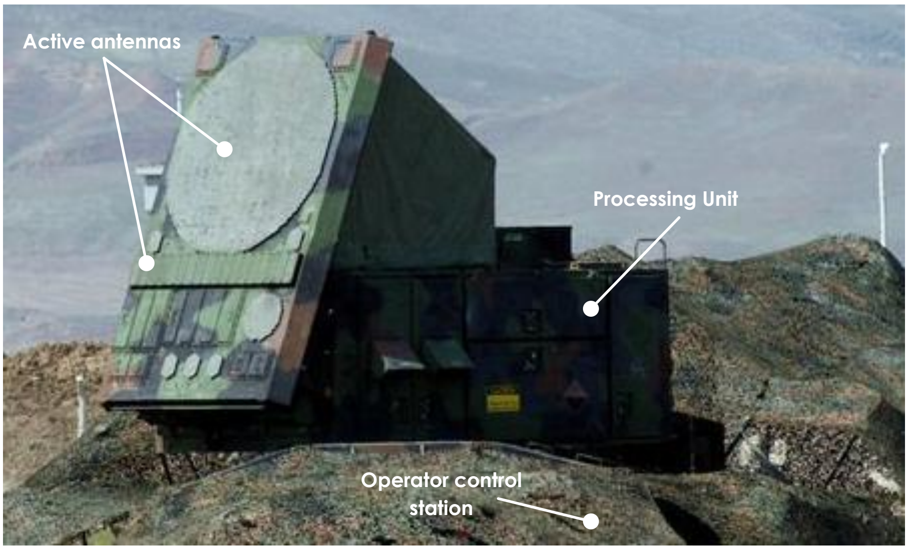

Fig. 1 : Phase array Radar (Patriot).

Each elementary radiating elements, the TR module, are controlled independently in phase by the processing unit to form the radar beam. The number of TR modules could easily be higher than 100 for on boarded radar and higher than 1000 for larger antennas; interconnecting all the TR modules together is really challenging and become now days the network bottleneck. Optical communication withn the antenna, is therefore needed to overcome the bandwidth needs and to reduce the Electromagnetic Interferences (EMI) sensitivity. D-Lightsys optical transceivers and parallel interconnect solutions are good candidates as they have been designed for severe environment applications with the world smallest form factor and the lower power consumption.

Full optical interconnect radar architecture

A full optical interconnect radar architecture is detail in this paragraph, we describe where optical solution could be integrated to benefit of fiber and optical communication advantages. The network architecture described here, allows a simpler with higher performances, light weight and scalable radar design. A simplified full optical interconnect architecture is presented on fig.2. In this architecture, the fiber is used from the radar processing equipment up to each TR Module and down to the control station.

The antenna is composed with several TR modules connected through an interconnect matrix. An optical link is proposed to provide the information from and to the processing unit located behind the antenna or several meters or kilometers away. The processing unit is mainly based on a parallel architecture to overcome the bandwidth and computing needs. Each sub processing nodes exchange data with the others to form the beam and decode the received signals. The treated information is therefore routed to the control and display station to operate the eventual missile launch or the counter measure appropriate.

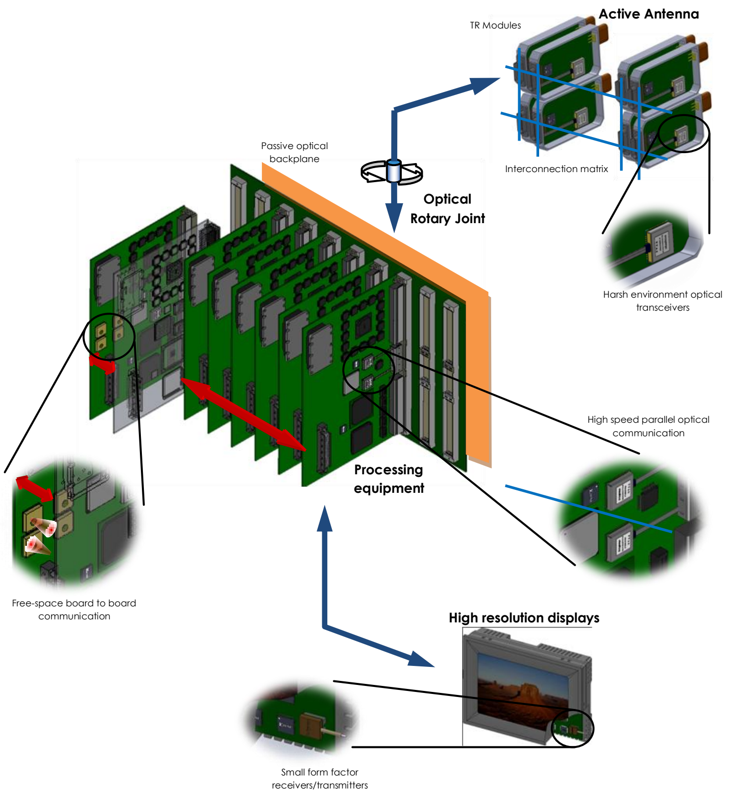

Fig. 2 : Full optical network active antennaradar architecture.

Active antenna

The TR modules that composed (fig. 3) the active antenna integrates a radiating element (the antenna itself) followed by a circulator/duplexer that connect the antenna to the transmitter power amplifier (PA) or the receiving low noise amplifier (LNA). The phase of the local oscillator (LO) is controlled through a digital circuit by the processing equipment. The received signal, after amplification and filtering, could be digitalized and transferred to processing equipment.

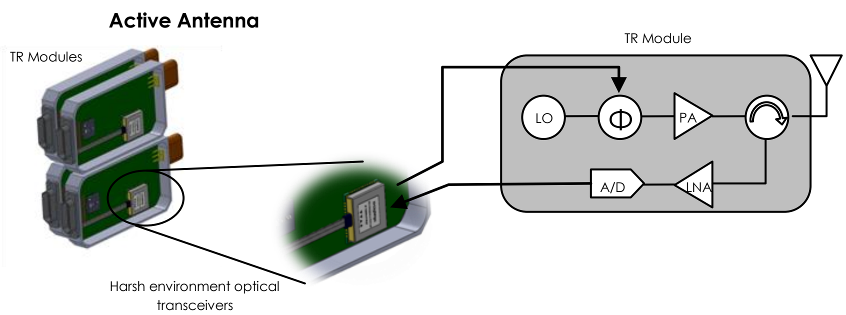

Fig. 3 : TR module details.

to D-Lightsys highly integrated optical transceivers, the E/O conversion could be achieved directly within the TR module. Both the phase controlled data (low bit rate) and the digitalized "video" signals could be transmitted over fibre. The main benefits of this architecture are:

- No need of expensive low loss SHF cable, as the fibre losses are negligible.

- The antenna wiring is simplified as it is not EMI sensitive, the fibre cable bending radius are much lower than the SHF cable.
- Lighter antenna, especially interesting for on board radar.
- Antenna could be physically separated from the processing equipment from meter to kilometer by using optical fibre communications.
- Use of cheaper, lighter and integrated rotary joint.

The E/O conversion, according to the TR module bandwidth and radar application, could be done at sub-system level, integrating several TR module in a sub-system. The sub-system generally regroups 4, 8 or more TR modules and E/O conversion is done in the backplane of the electrical interconnect layer.

A optical active or passive interconnect matrix could be used to simplify the wiring and allow some switching pre-/post- processing at the antenna level.

Processing unit

The processing unitis retrieving the information to the antenna. Beam forming algorithm, Fast Fourier Transform and several other mathematical operation are done on the signals to provide to the operator or system the relevant application. This equipment is mainly a rack mounted distributed DSP/processors/FPGA computing boards interconnected through a dense high performance backplane exchanging intermediate processing results in real time. The bandwidth demand could very high to maintain the real time requirements and optical interconnect solutions could achieve this.

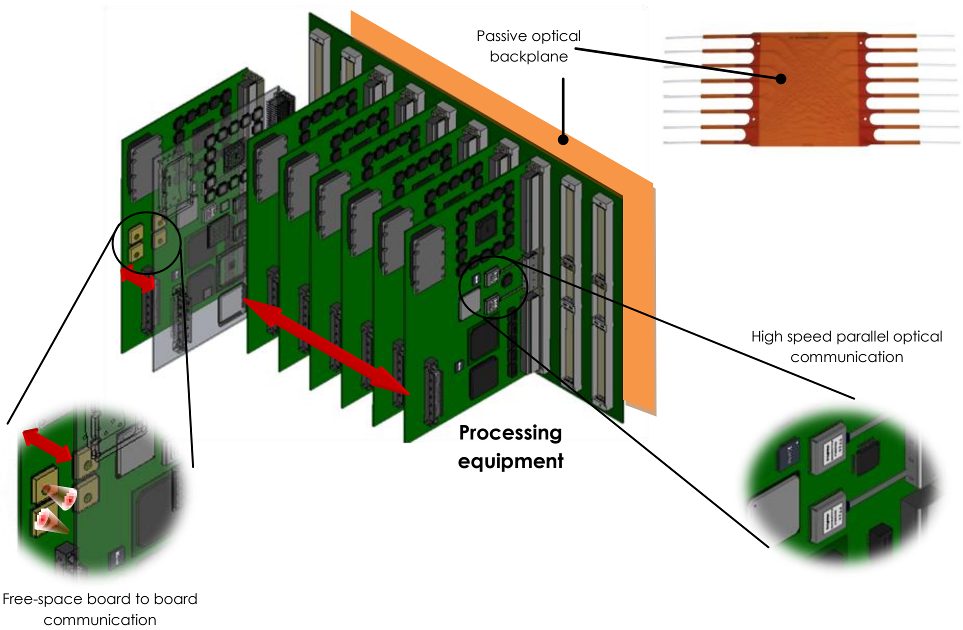

Fig. 4 : Processing unit details.

D-Lightsys offers two types of optical transceivers/modules that could be used directly in the processing unit: Parallel optical modules (D-Light Family) could be used to interconnect the boards together, a single module package could handle an overall bit rate of 50Gbps to 120Gbps (12 channels at 4.5Gbps/ch or 10Gbps/ch). One couple of multiple channel Tx and Rx module could be place onto the processing board or a mezzanine one and interconnected to a passive optical mesh backplane. The optical backplane could be designed and changed according to a specific mission profile without modifying the electrical backplane. The fig. 4 present a flexible optical backplane that realize a 8x8 interconnection matrix.

Free-space optical interconnect (FSOI) solutions could also be used to communicate from board to board within the processing rack. D-Lightsys recently introduce a family of product (F-Light) designed for short distance optical communication ranging from 1cm up to 60cm with misalignment tolerances compatible with rack vibration and alignments: with lateral misalignment of +/2cm and angular misalignment of +/-1°. This solution simplify the design and the manufacturing of the electrical backplane as no high speed tracks need to be routed though the backplane connectors and long distance. Thanks to a expanded beam design, the F-Light solution is dust and humidity robust and compatible with differential board vibrations. Simple holes in boards allows communication from one board to any others. The main advantages for FSOI into the processing unit is the power consumption reduction (no need for pre-emphasis/equalization techniques), design simplification, increase of mission scalability, cost reduction.

Display and control station

The human interface allows the radar operator to assign mission and retrieve the treated operation in order to operate missile or counter measures. The control station is sometime far from the processing unit or antenna and need optical communications compatible with field operations to match the distance/bandwidth requirements.

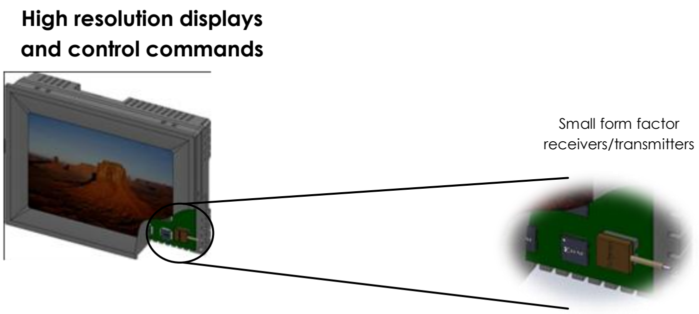

Fig. 5 : Full optical network active antennaradar architecture.

High performances, and very low profile optical transceivers are needed to enable high resolution displays. With a very small form factor package (12x13x5mm) S-Light devices are perfectly adapted for such applications as they are compatible with ARINC 818 standard and allows 3.125Gbps communications over 500m using a multimode 50/125µm fibre.

Conclusion

The wide D-Lightsys high performances optical interconnect offer covers the whole communication needs for high performances phased array radar. Radar could benefits of the main advantages of optical communication (low weight, galvanic isolation, EMI insensitivity, integration, scalability and reliability) from the TR module down to the control/display station via the processing unit thanks to D-Lightsys products.