# Photonic Technologies for Spaceborn Beam Forming Networks

## *Optical Beam Forming Networks in Selex SI*

***Luigi Pierno***

*ESA- ESTEC 21° November 2008*

SELEX Sistemi Integrati

# Outline

- Architectures for Optical BFN and routing for M-AESA
- COTS and critical optical components for OBFN
- R&D activities in Selex SI
- Conclusion

# Advantages of OBFN in Terrestrial, Naval, Airborne and Spaceborn M-AESA antennas

•Low weight , size , EMC typical of fiber optics

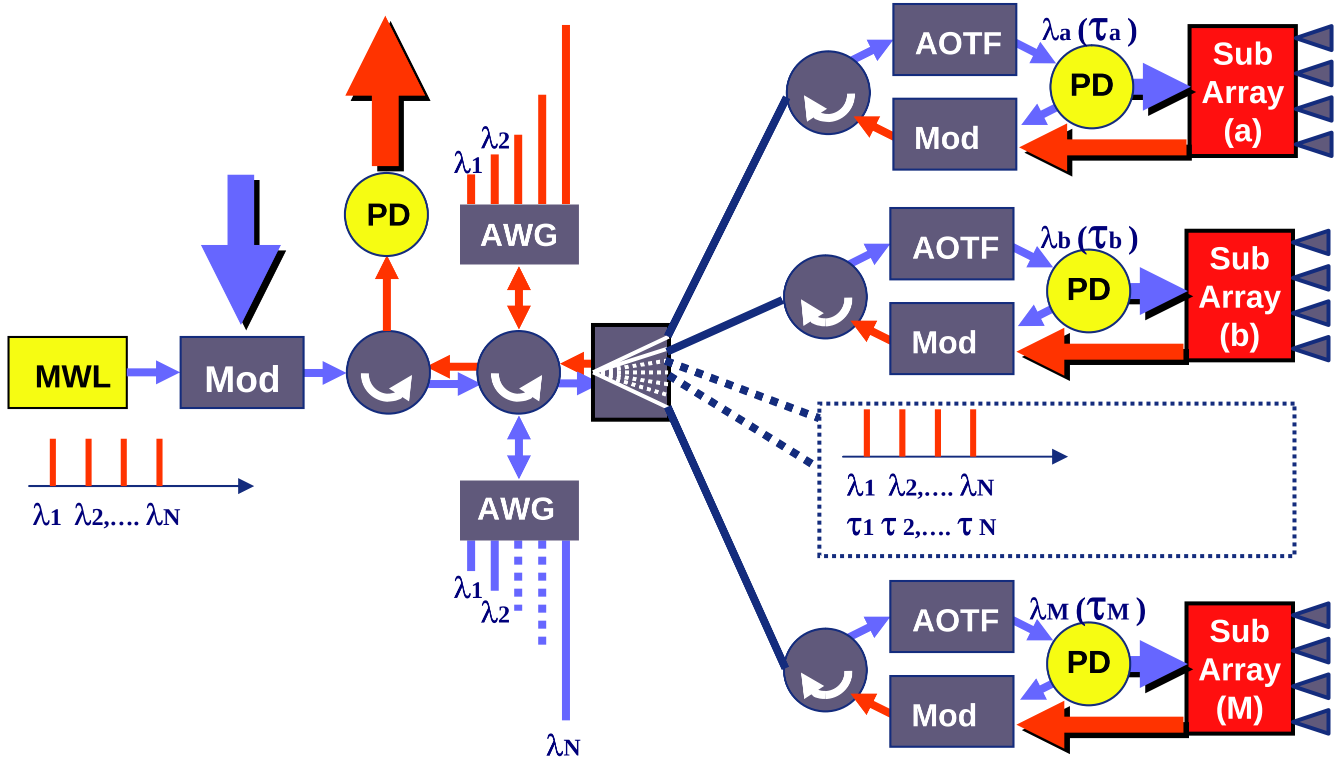
•True Time Delay (**squint free**) approach

•Wide **bandwidth** (>30 GHz ) of optical analogue or digital transmission (for Multi Role Antenna)

•Smart Antenna (dynamic **routing** among functions, low loss remoting of components)

•Optical Beamforming architecture applies to **analogue** and **digital** radar front end (Digital MF Radar)

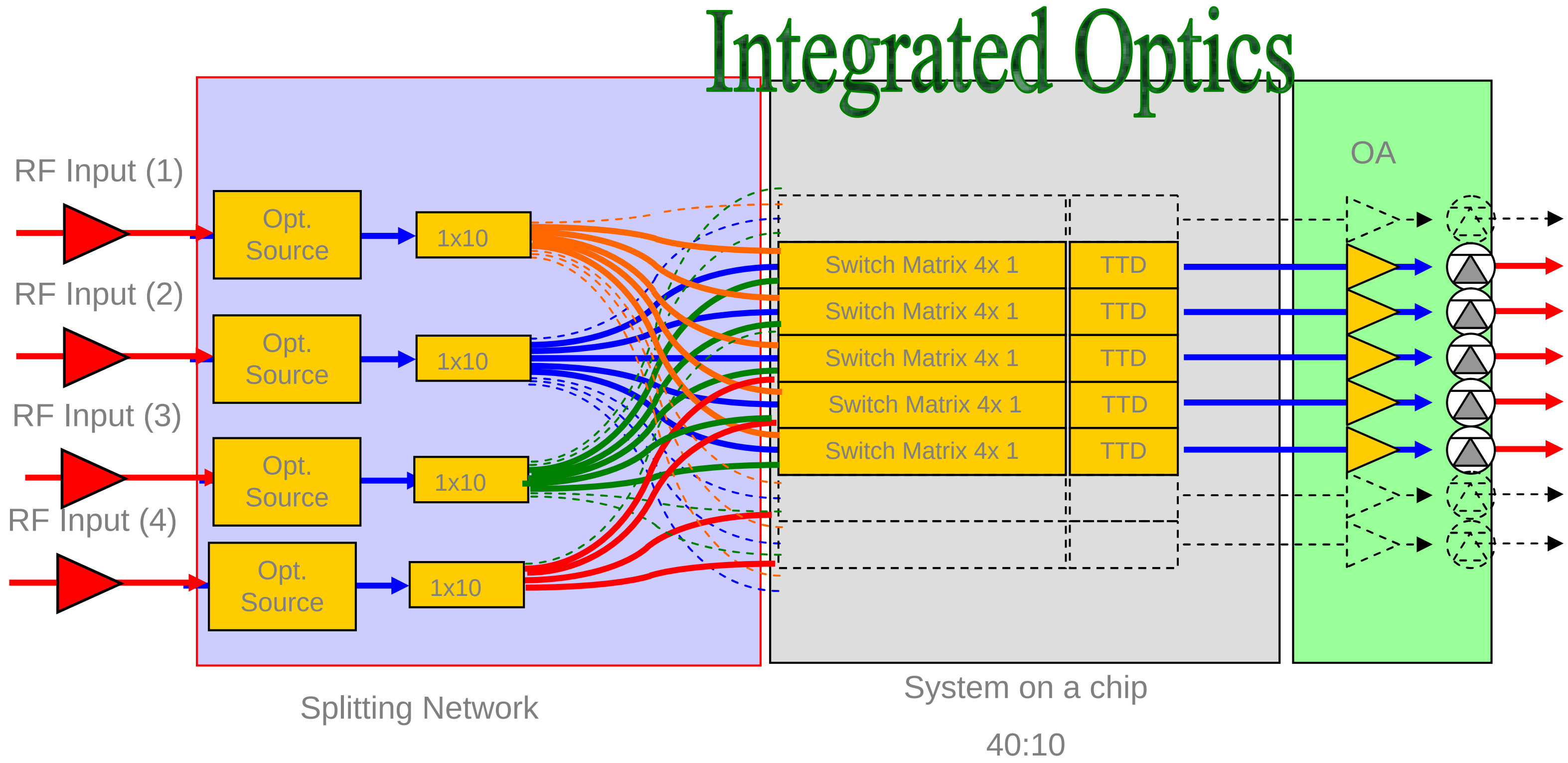
# Architectures for OBFN:
# Wavelength Domain Multiplexing




❖Wavelength ← → Fiber Optic Delay

❖Based on ElectroOptical or AcoustoOptical Tunable Filters

# Architectures for OBFN:
# Time Domain Multiplexing for COSMO like antenna




TDM Architecture for multifunctional COSMO like antenna (Transmit mode)

Ref: 28th Antenna Workshop on Space Antenna Systems and Technologies
DIGITAL OPTICAL SWITCHES IN TTD FOR SPACE ACTIVE ANTENNAS
**ESA ESTEC** Mauro Varasi, Luigi Pierno, Massimiliano Dispenza, Roberta Buttiglione, Fulvia Verzegnassi
**21° November 2008**

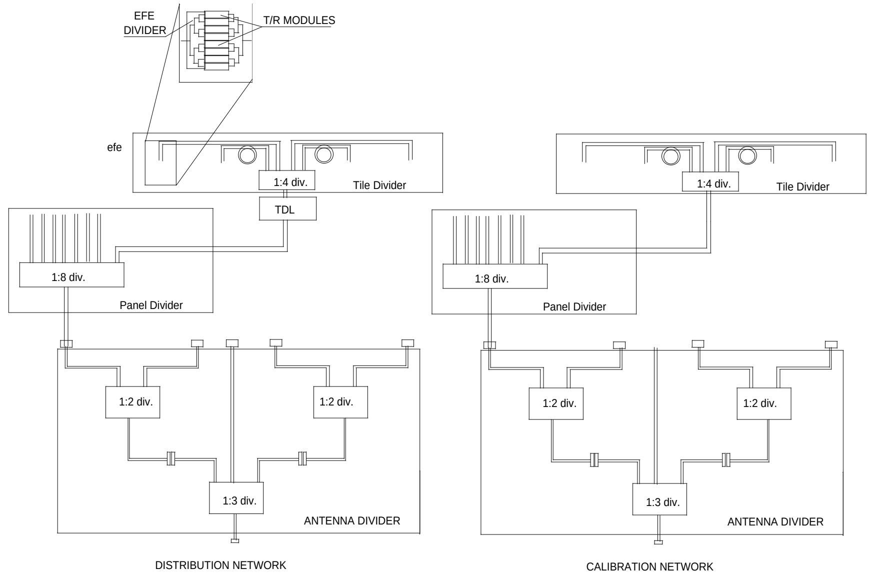
# OBFN advantages in COSMO like antenna

| *Parameter* | *Proposed TTD* |
|---|---|
| TTD modules | 40 |
| TTD required | 15 λ |
| N° of bits | 5 bits<br>(0,47 λ = 1 bit) |
| Rec. speed | < 10 nsec |
| Optical Losses | 18dB |
| Volume | 12 x 12 x 2 $cm^3$ |
| Power consumtion | 1mW |
| Mass | <10g |
| Cross Talk Extinction | 30dB |
| Optical Extinction | Negligible |
| Optical Crosstalk (single TTD) | 60 dB |

*HighSpeed of reconfigurability of Optical Beam Forming Network due to the Electrooptical drive of the devices*

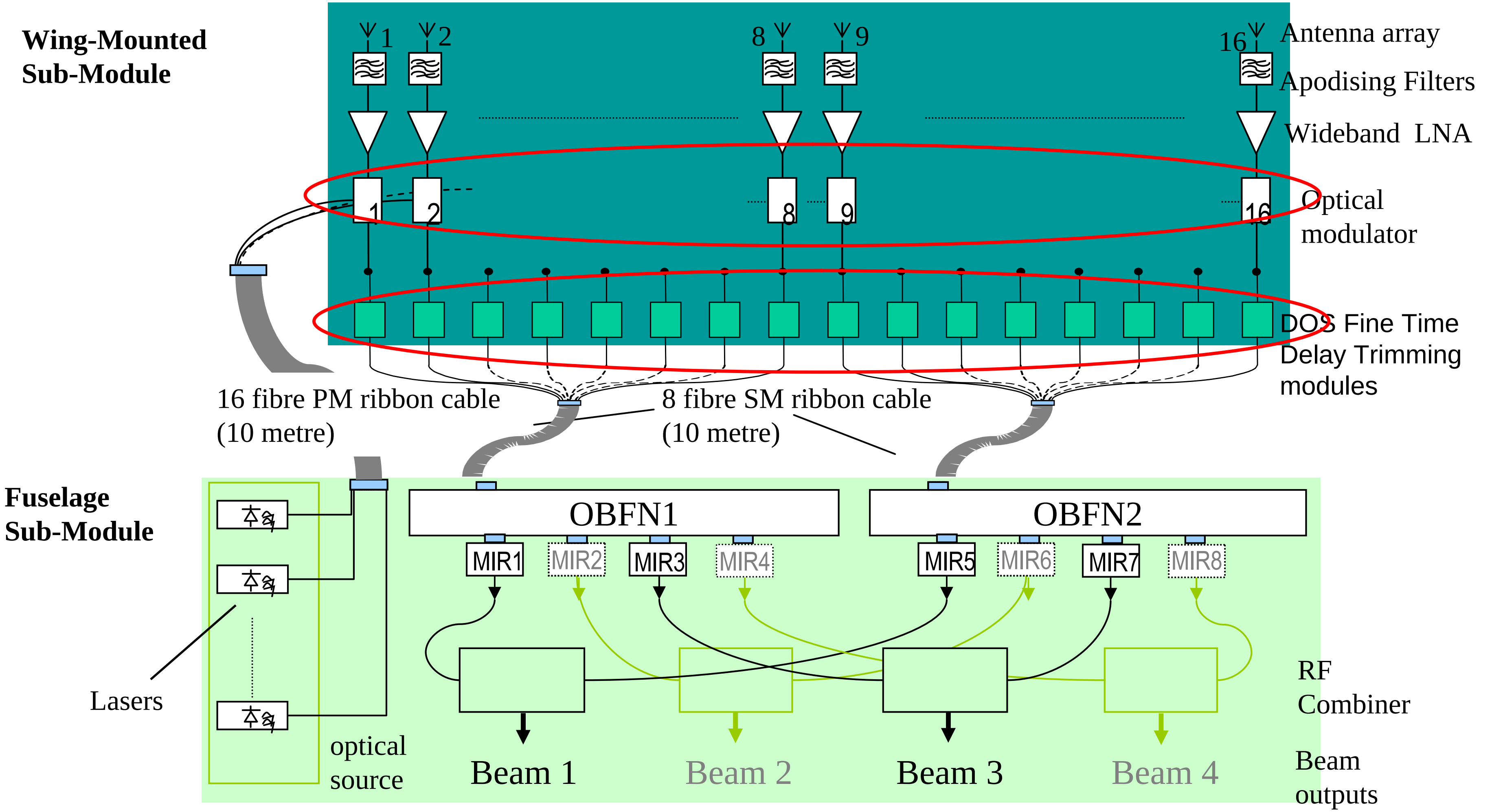
$$\delta z := H \cdot \sin(\theta) \qquad Step \cdot \lambda_c = \frac{\delta z}{2^N}$$

*High degree of integration →Suitalble for satellite payload*



# Architectures for OBFN: EWOCS(*) project

## Demonstrator Architecture for Receive operation

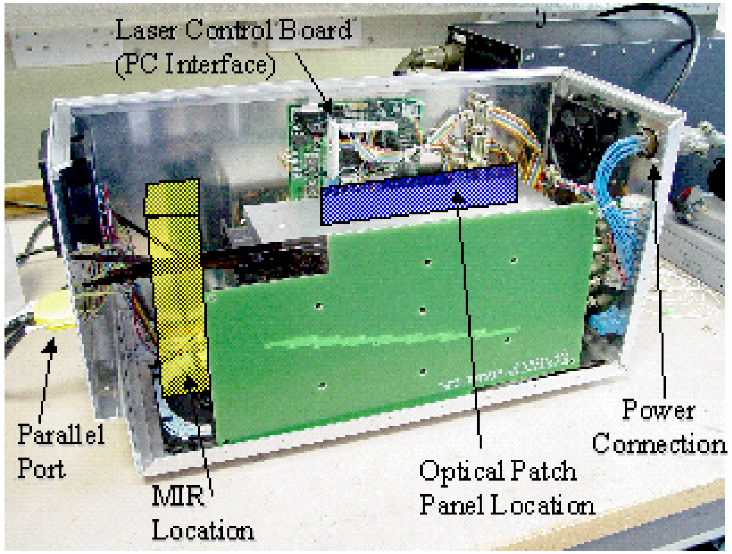


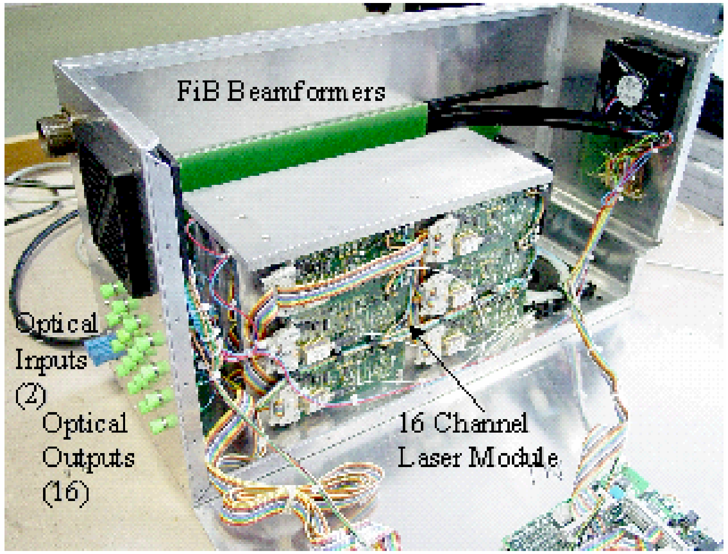


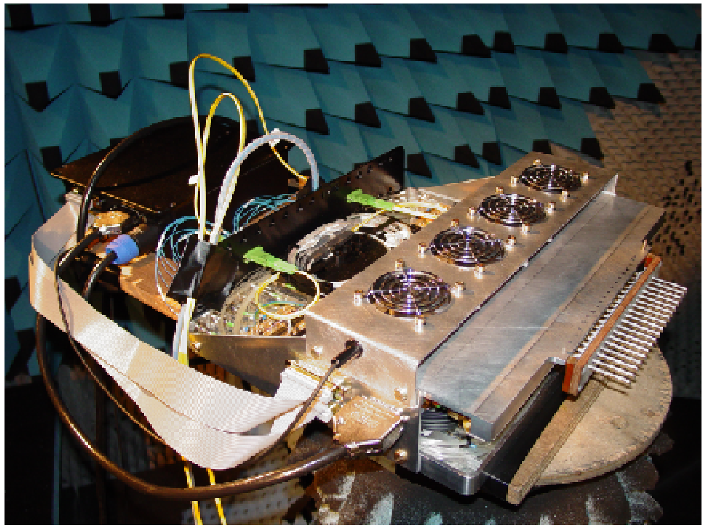

*(*) EDA project in partnership with BAE Systems*

# Photonics components for OBFN: EWOCS

Fuselage Module & Wing-Mounted Module

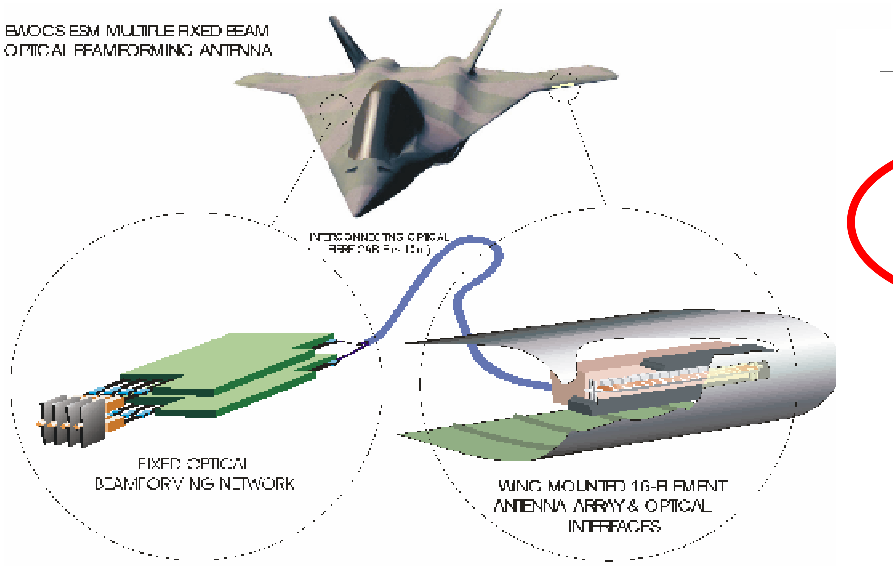


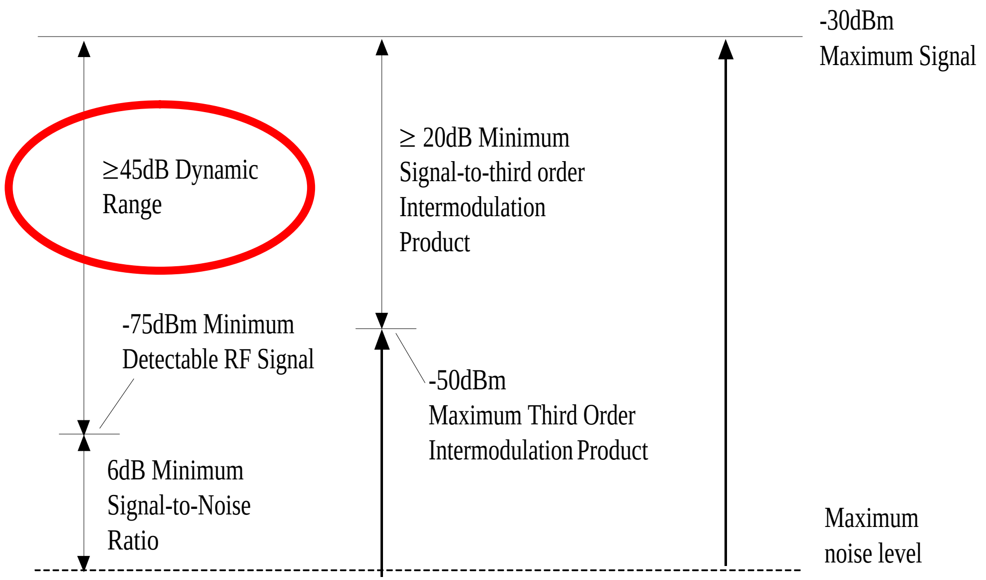



❖**Based on Selex SI Modulators**

# Performance of OBFN: EWOCS project



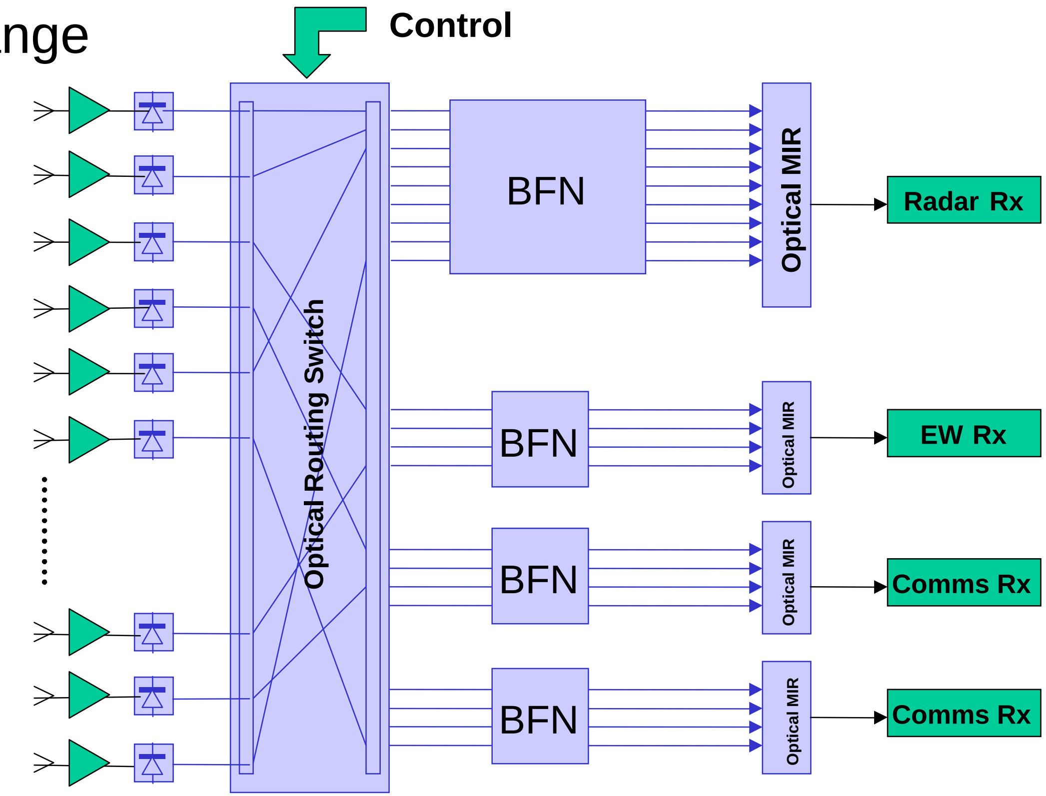

- ❖6-18GHz frequency coverage
- ❖4GHz instantaneous bandwidth
- ❖16 antenna elements (in a linear array)
- ❖Angular coverage/TTD array: ±45o azimuth, ±45o elevation
- ❖Adjacent beam crossover: 3 - 8 dB below beam peak
- ❖Next adjacent beam crossover = 20 dB below beam peak and greater than the highest sidelobe

# Optical Routing and Beamforming Architecture

SELEX Sistemi Integrati

MORSE (*) Project Objectives

- ❖Multifunctional Antenna (S&T, Comms, Synthetic Aperture Radar for Imaging, ….)
- ❖Dynamical Reconfigurability of the aperture
- ❖Wide bandwidth
- ❖Linearity - Dynamic range
- ❖Scalability
- ❖Reliability

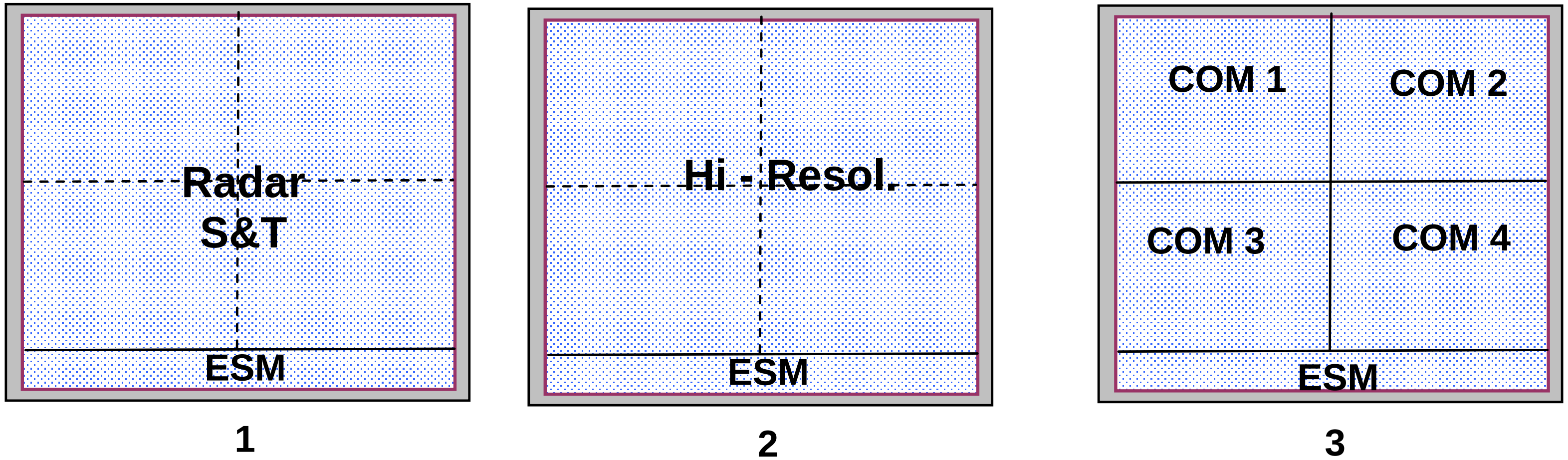



*(*) EDA project in partnership with BAE Systems, SAAB*

# Optical Routing and Beamforming Architecture

Morse Key features

❑Antenna architecture must enable dynamical reassign of portions of antenna aperture while ensuring simultaneous operation of e-m functions



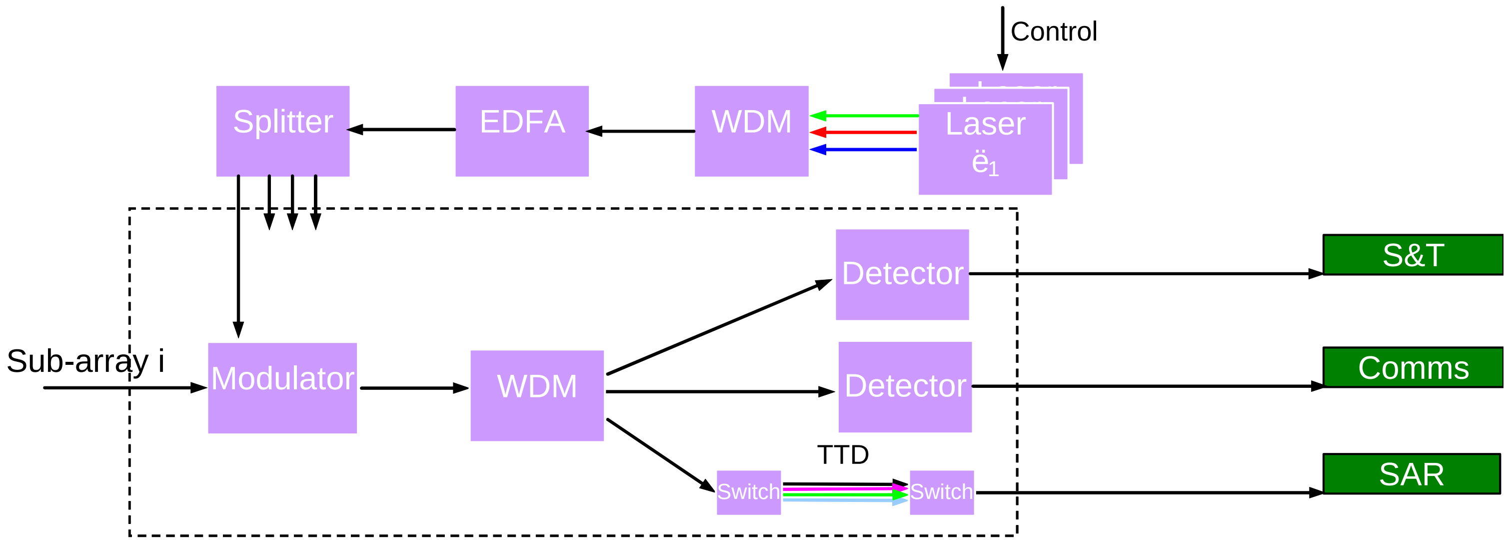

Example of 3 possible antenna apertures

# Optical Routing and Beamforming Architecture

Morse Key features

❑Alternative approaches to be employed for multiple functions to be implemented and dynamically reassigned will be evaluated:

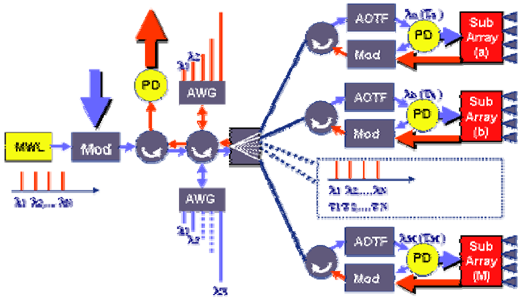
- ✓Space Multiplexing by Integrated Optical Switching Matrixes
- ✓Wavelength Division Multiplexing by tunable lasers/ filters, multiwavelength lasers …

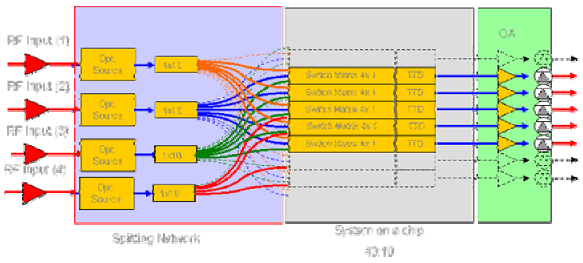


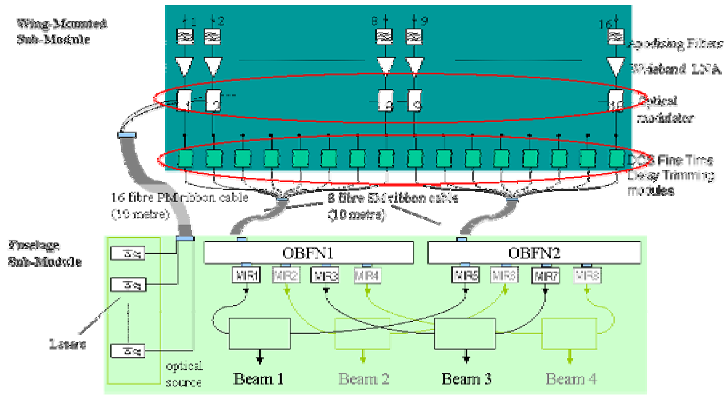
# Architectures for OBFN: Key approaches

SELEX Sistemi Integrati

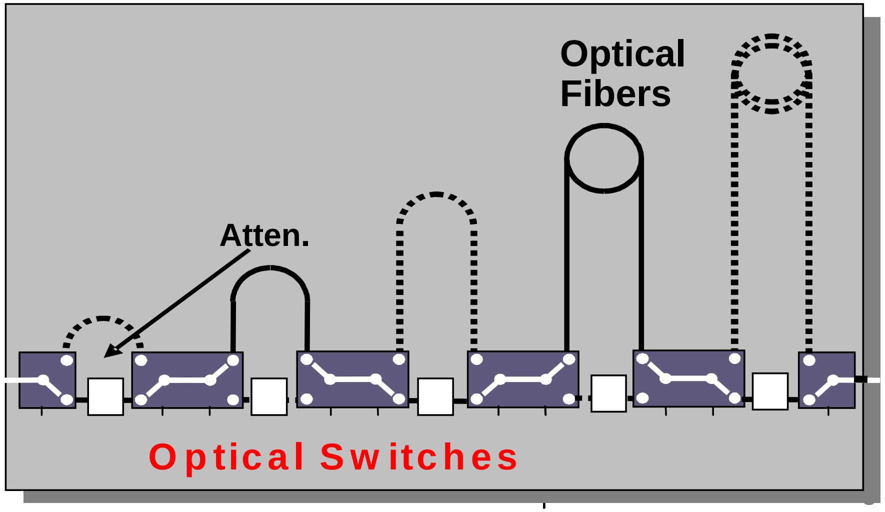
| Functionalities | Technical approach | Critical Devices |
|---|---|---|
| True Time Delay Beam Steering | Changing the physical path | ✓**Optical switches** |
| | Changing wavelenght in dispersive media | ✓ **Optical Tuneable filters**<br>✓**Multiwavelenght lasers** |
| M-AESA: Routing among Functions (also digital front end) | Space Domain Routing | ✓**Optical switches** |
| | Wavelenght Domain Routing | ✓**Tuneable filters**<br>✓**Multiple lasers + passive filters** |



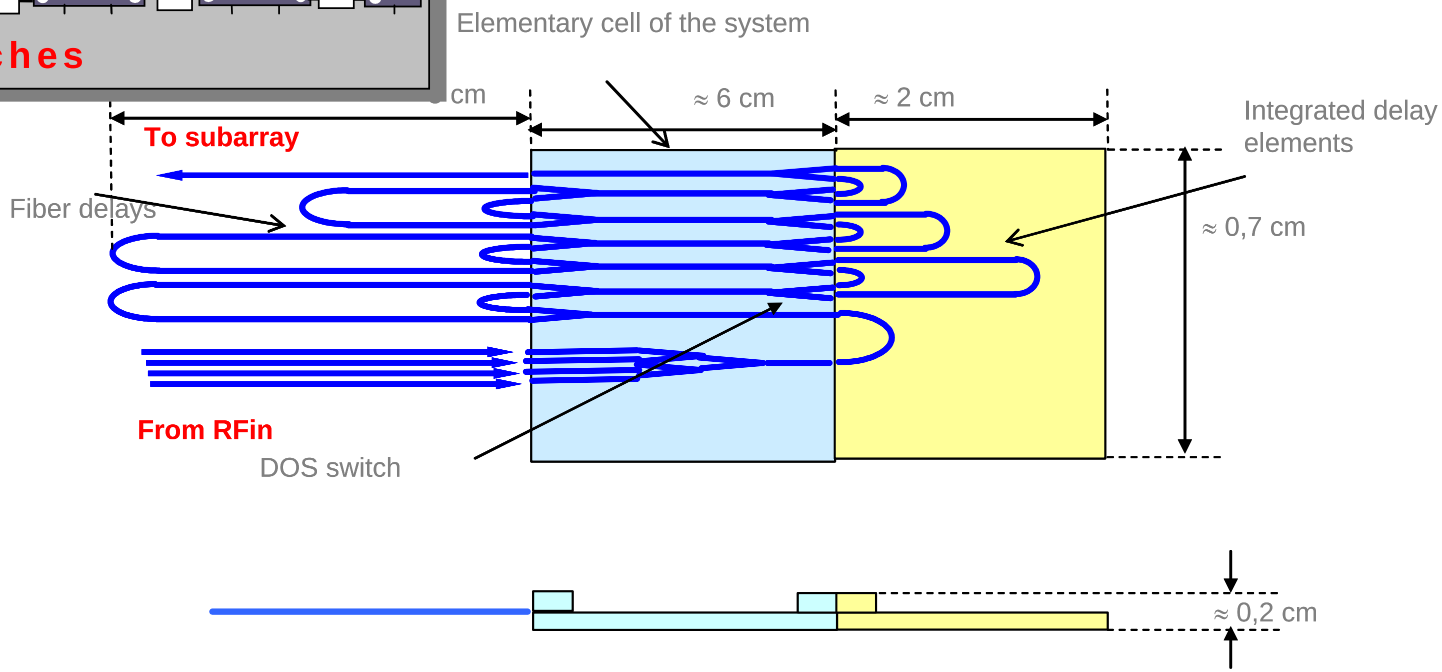





# Switchable True Time Delay Unit



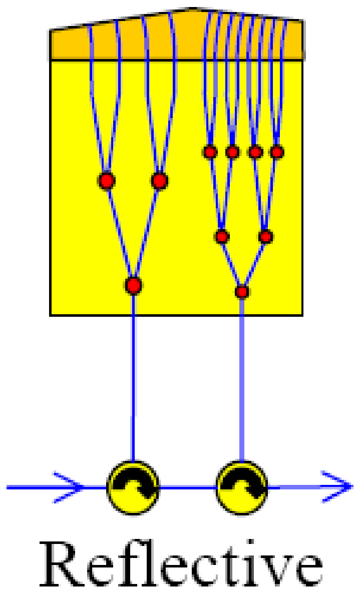

❖Integrated Optics TTD
→ high speed (10ns) for beam steering

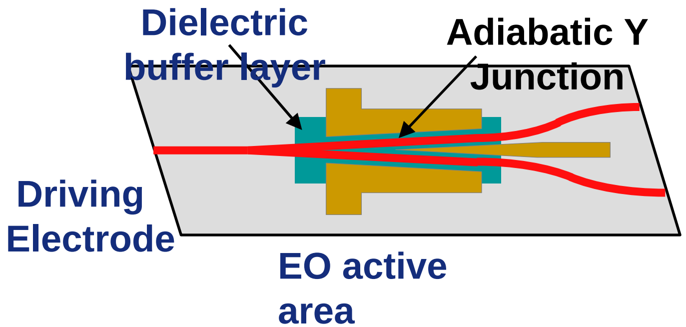


# Photonics components for OBFN

## Digital Optical Switches Reflection TTD

❖Lower Insertion Loss
❖More Stable operation
❖DOS integrated with time delay waveguide chip
❖More compact delay module
❖Minimum delay increment for 2 Bit Fine TTD: 0.1ps



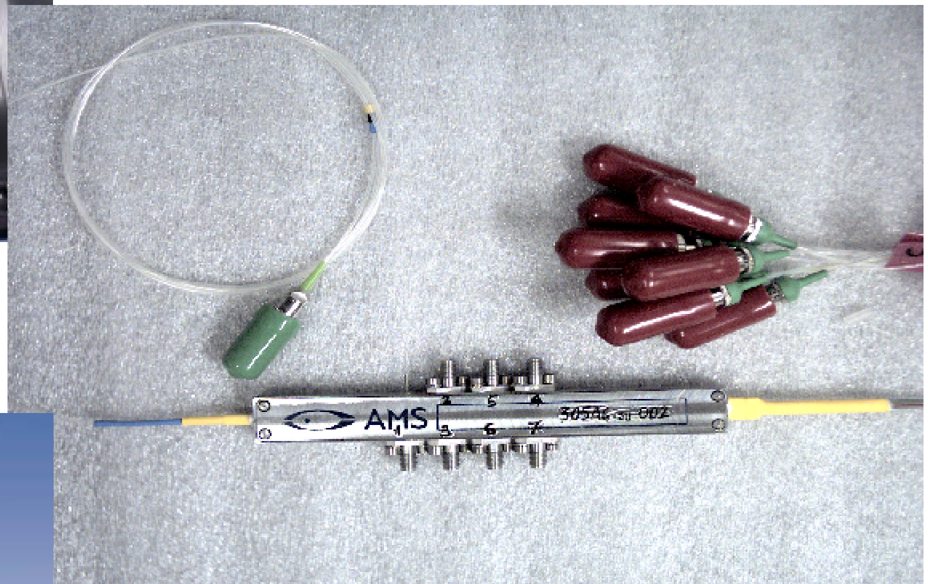



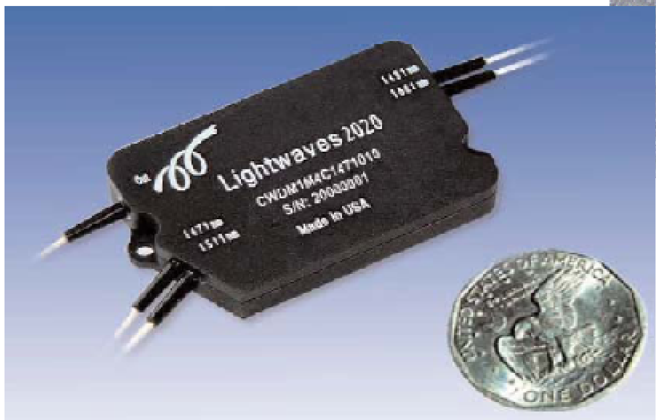

## True Time Delay for fixed beams : Fiber in Boards (BAE)

# Components for OBFN and routing

❖Array of 1X4 MagnetoOptical Switches for routing matrix in Space Multiplexing (Speed 1 us, Optical Losses 1 dB)

❖1X8 DOS matrix from Selex SI (Speed 10ns, Optical Losses 7 dB)




❖WDM mux for WDM based OBFN (Optical Losses 1 dB)

# R&D activities in Selex SI

- **R&D Projects:**
  - ✓PNRM 156: Optical Processing of Microwave Signals (2004)
  - ✓EWOCS: Electronic Warfare Optically Controlled Subsystem (2006)
  - ✓MORSE: Multifunction Optical Reconfigurable Scalable Equipment (Running Project)

- **Main objectives**
  - ✓True Time Delay Optical Beam Forming Networks for Phased Array Radars
  - ✓Optical Beam Forming and Optical Routing in Multifunction/Multirole AESA

- **Future Perspectives**
  - ❑Implementation in the routing network of the distribution of LO for RF signal downconversion in antenna front end → Digital MF radar

# Conclusion

- Optical Beam Forming Networks have a big potential in the application to M-AESA antennas in satellite payloads due to low weight , size EMC compliance and wide BW
- Prototypes of OBFN are based on COTS and on some integrated optics components for improved dynamic range, speed of Beam steering and size, weight
- Research funded by Ministry of Defence in this field is going on in the last 10 years for Terrestrial, Naval, Airborne, applications
- The achieved solutions are reusable for the Satellite payload antenna and also for future Digital front end Radars
- Selex SI is still involved in activity with running project that addresses OBFN and Optical Routing