Phased Arrays in Satcom ... why?

- **Flexibility!!**

→ power allocation per beams much more easy than in SFPB
→ coverage modification in active Phased Arrays

- **Robustness**

→ Graceful degradation (you can loss elements with minimum impact on the radiation diagram)

... how?

- **Digital Beamforming**

→ Trend of today's DRA (Quantum from EUTELSAT, for example)
→ The maximum flexibility → but at the expenses of large power consumption!
→ for limited number of beams

- **Analog Beamforming** ..may be photonics?

→ A number of options implemented …. All of them bulky

Phased Arrays in HTS … what is needed?

- **<u>Hundreds of beams & antenna elements (HTS) !!!!</u>**

- High accuracy in phase and amplitude weights
  → Side lobes, beam pointing…
- Extremally complex HW
  → Antenna, power amplifiers, BFN, distribution together!!
  → Calibration is a challenge
- Broadband (BW > 500 MHz, probably > 2 GHz with beam-hopping) → beam-squint could be an issue.
- Linearity requirements
  → all antenna elements radiates all the beam signals
- Losses & NF
  → in Tx, losses to be compensated in the antenna (Power, complexity, reliability)
  → in Rx, NF impacts on the G/T… so you need more gain!

How photonics can "try" to help?

- Hundreds of beams & antenna elements (HTS) !!!!

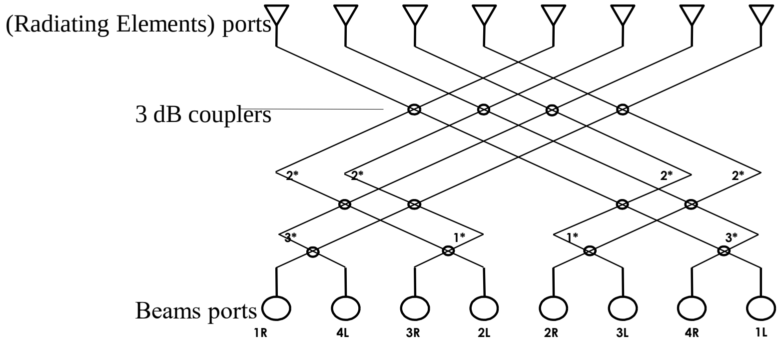
  → scalable structure… probably fixed BFN could be enough
- High accuracy in phase and amplitude weights
  → optical heterodyne probably not enough… but homodyne yes?
- Extremely complex HW
  → use optical fiber to remove the BFN from the antenna assembly
  → try to maintain control complexity as simple as possible
- Broadband (BW > 500 MHz, probably > 2 GHz with beam-hopping)
  → TTD (full or partial) could help… but only needed for very large BWs
- Linearity requirements
  → linearity of the photodiodes should be low!
- Losses & NF
  → probably is the major issue… (remember we are thinking in hundreds of antennas and beams)
  → we can try to increase power… but with certain limit (especially in PIC), and at the expenses of power consumption.

DAS Photonics

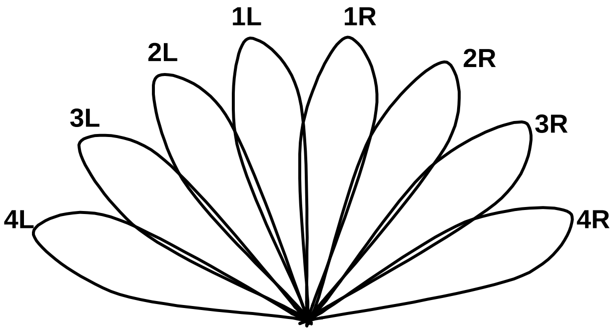
Photonic RF beam-forming. FIXED COVERAGE

From ICSO 2014

One dimension Butler Matrix (8X8)

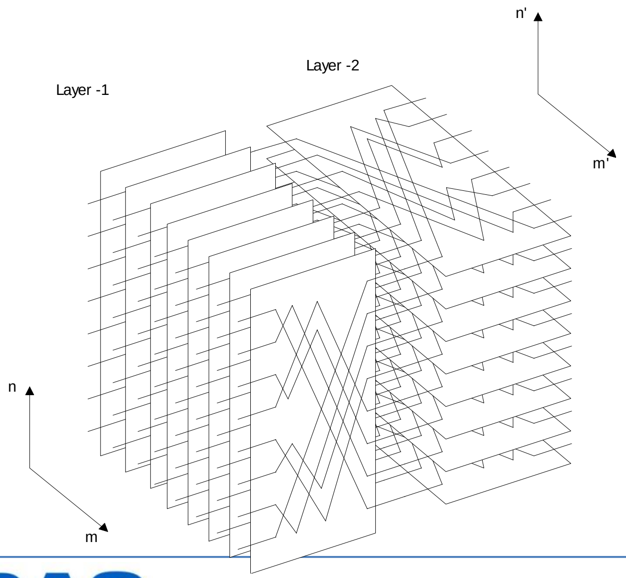


Antenna Patterns

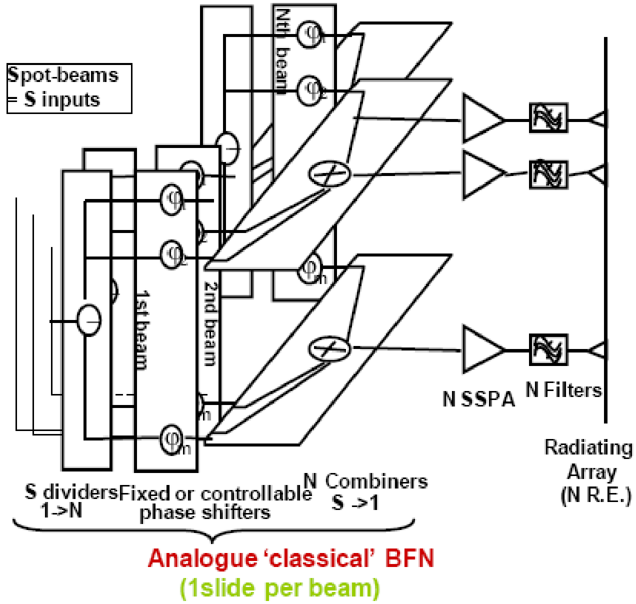


For 8 regularly spaced beams & 8 RE (Radiating Elements),
it **reduces NB of couplers from 112 in 2D structure to 12** in planar structure !

Two dimensions Butler Matrices set



For 64 regularly spaced beams (in 2D=8*8) & 64 RE, it needs **only 192 couplers, instead of 8064** for classical beam-former with 1 slide per beam & RE, or 1792 if split in 2 sets as Butler!

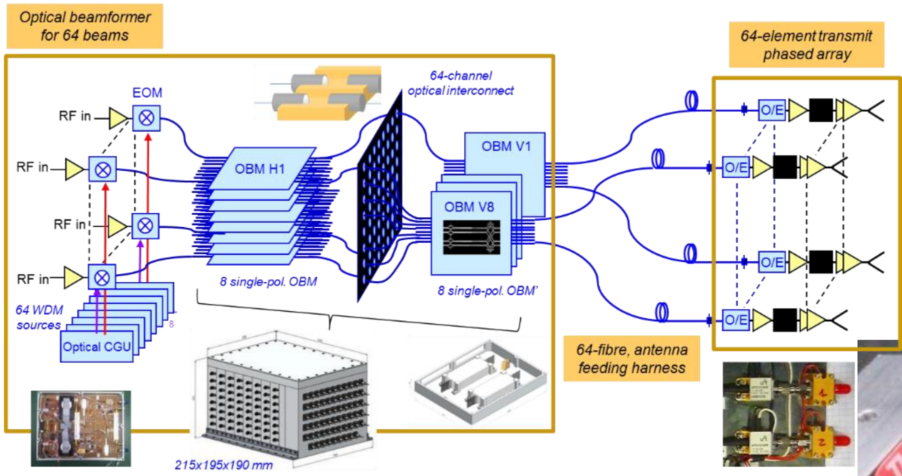


DAS Photonics

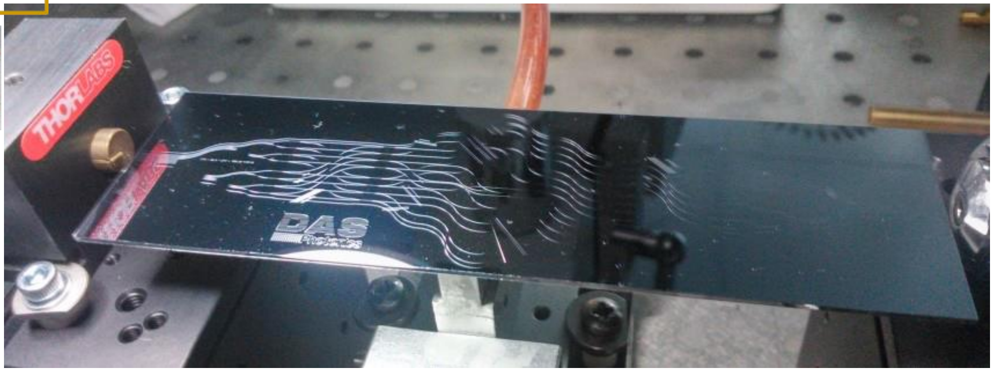
Photonic RF beam-forming. FIXED COVERAGE

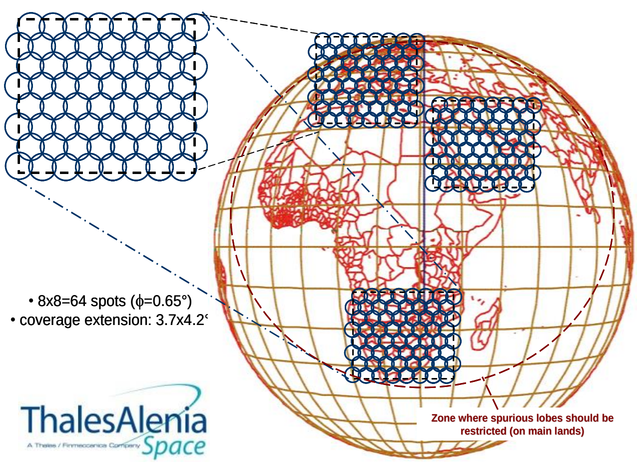
From ICSO 2014

Antenna system architecture



PIC Optical Butler Matrix 8x8





- Better phase accuracy and stability than RF counterparts
- NF & Losses affordable for practical use
- Design scalable up to 512 antennas/beams (patent pending)

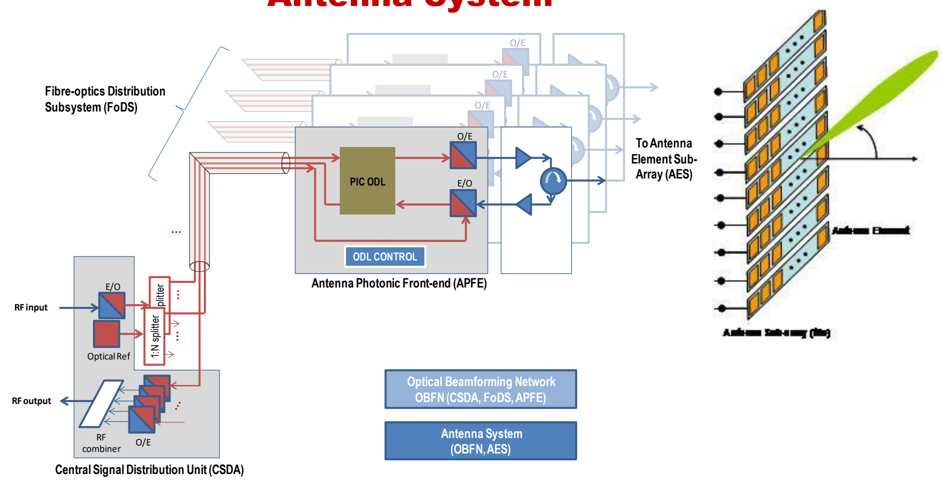
DAS Photonics

Photonic RF beam-forming. Tunable TTD

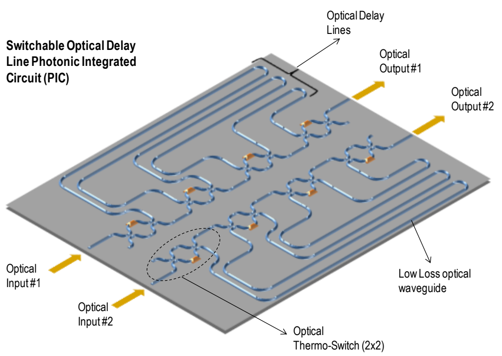
PIC & Fiber Optics distribution RADAR-SAR applications,

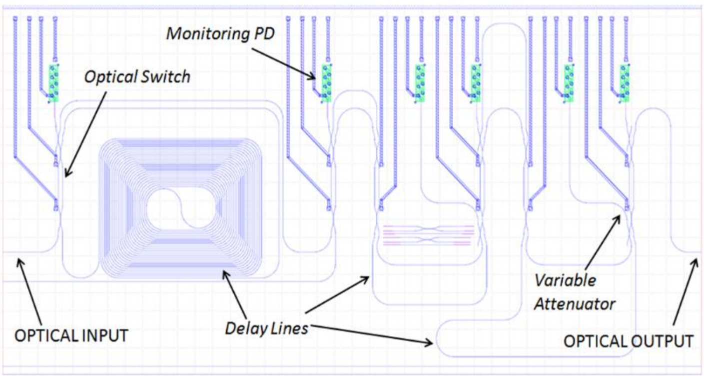
- **optical signal distribution** to the antenna,
- the **true-time-delay control** of the signal for each antenna element (PICs): TX/RX
- **optical harness for deployable antennas**
- **antenna array module in X band**.

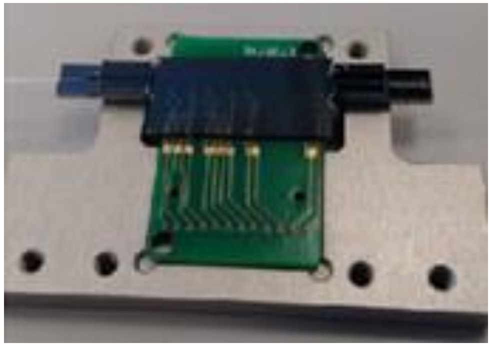
Antenna System



PHOTONIC CHIP







FP7 GAIA Project