ANALOG PHOTONIC NEEDS FOR PHASED ARRAY ANTENNAS

DARPA AOSP WORKSHOP
December 6, 2000

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Analog photonic needs for REAL phased array antennas

- **Tunable front-end RF filters**

  (It assumes the existence of low V_π modulators)

- **Low cost, miniaturized programmable delay lines**
  - **Analog RF manifolds**
  - **Analog/Digital manifolds**

  (It assumes the existence of low V_π modulators)

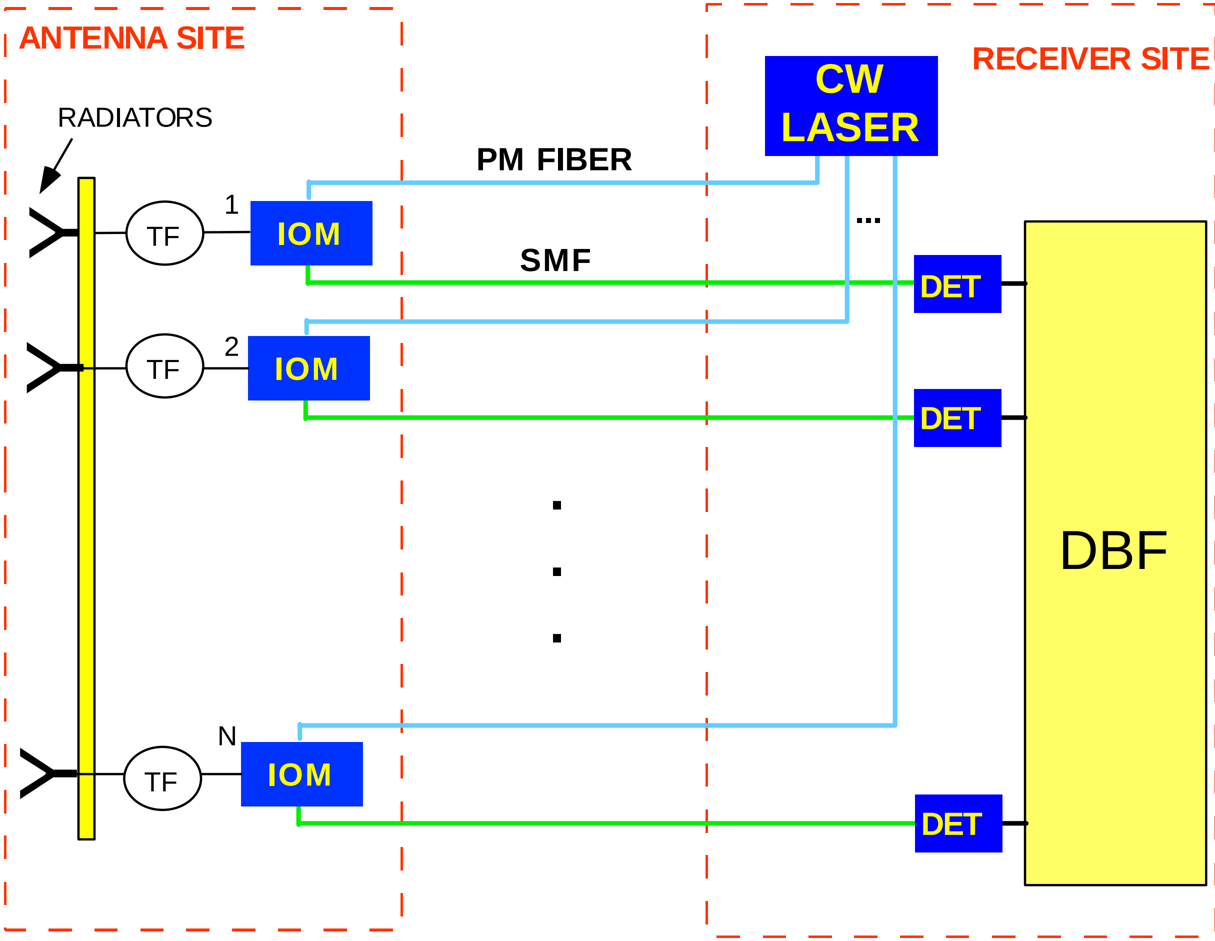
- **Tunable optical filter banks**

Need: *Optically-implemented RF tunable filters*

- Multi-octave systems suffer from 2nd, 3rd etc harmonic and other unwanted signals

- RF tunable filters at the front end is a must to eliminate unwanted signals and reduce ADC spurious effects

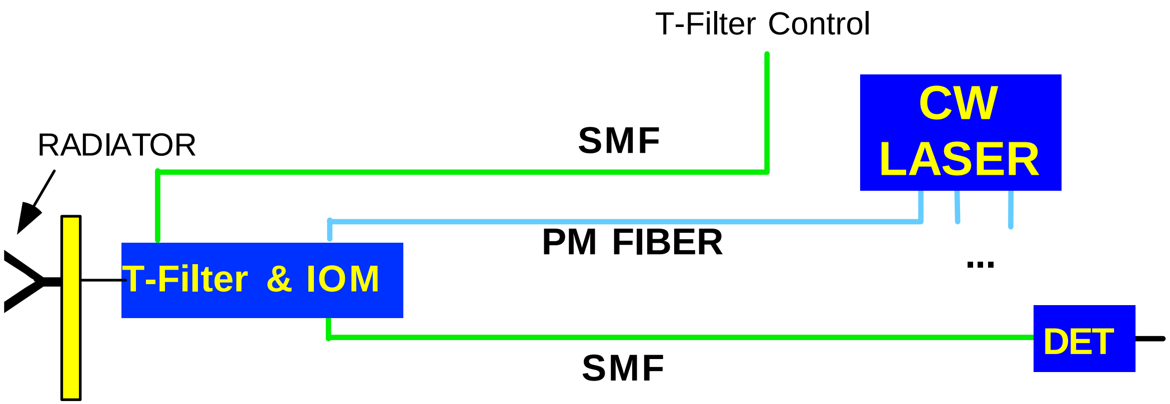
- Not an easy task for RF or MEMS technology



CAN WE MAKE A TUNABLE RF FILTER WITHIN THE IOM ???

Need: *Optically-implemented RF tunable filters*

IDEAL ALL-OPTICAL FRONT-END ARCHITECTURE



- Filter must have all-BW condition, and sub-octave tunable passband

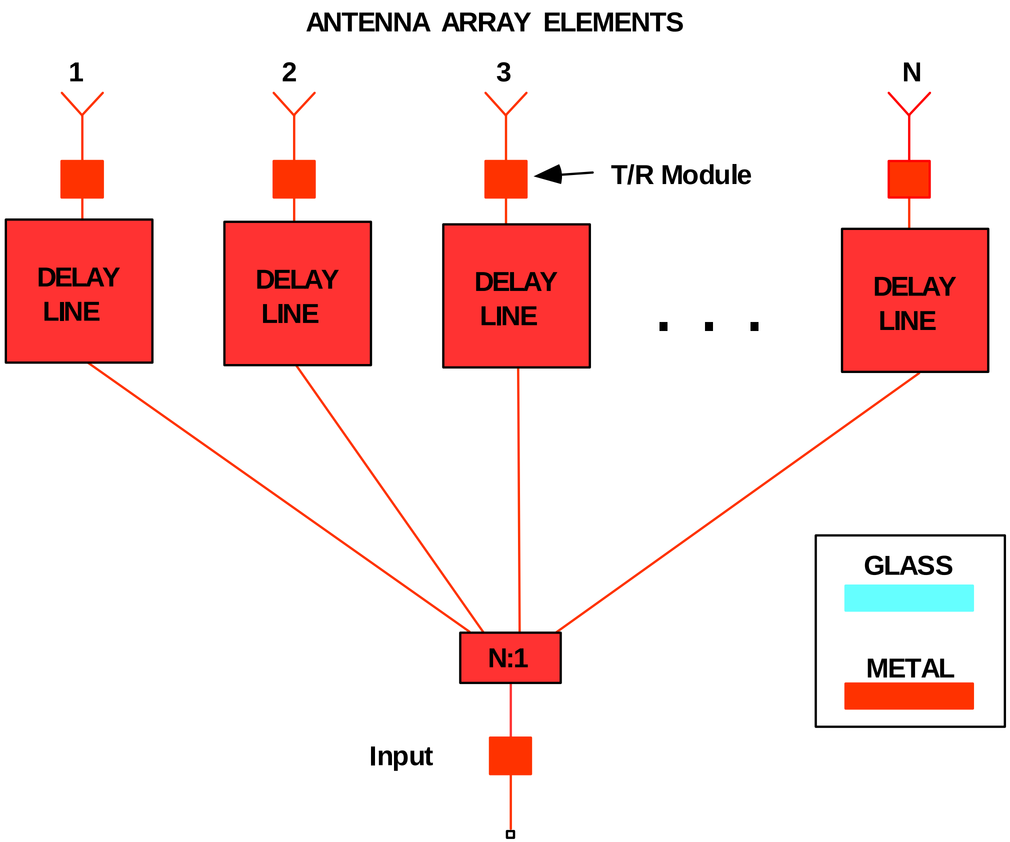
  Example for 2-18 GHz instantaneous BW

  (1) all-BW (2-18)

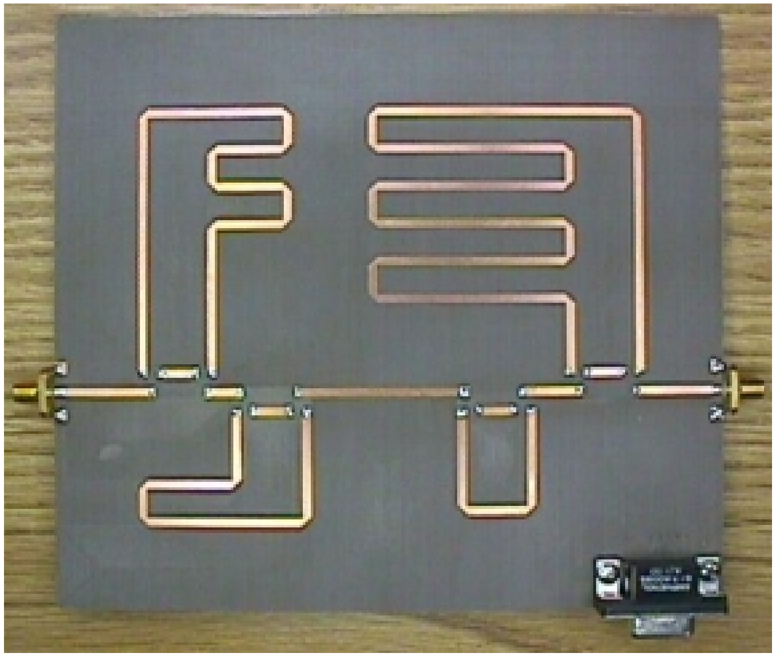
  (2) 2-4 GHz, 4-8 GHz, 8-12 GHz, 9-18 GHz
- Sub-ms speed OK
- Optical control is great (enables remoting with no wires)

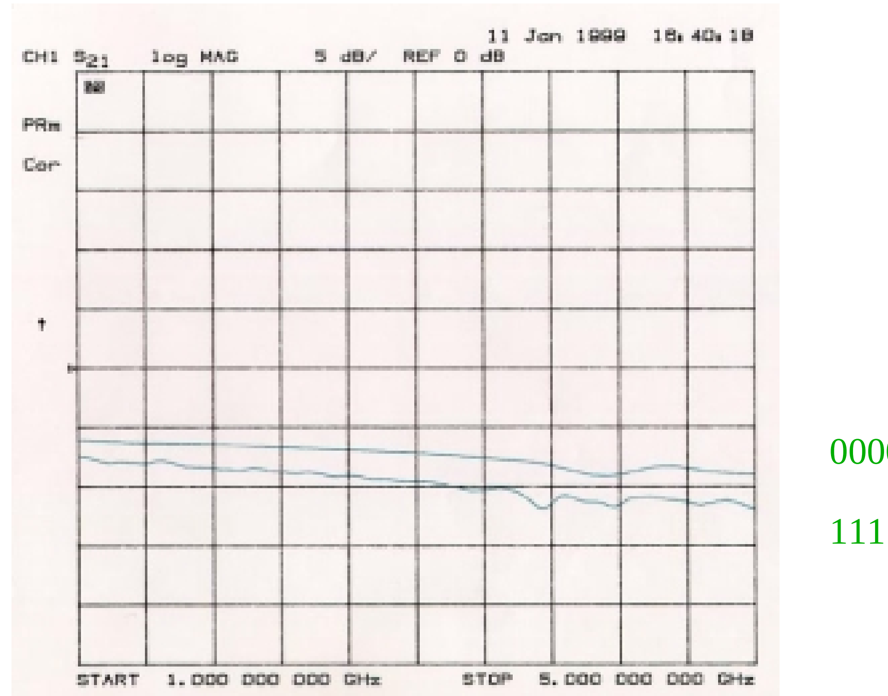
Need: *Low loss optical delay lines (analog RF manifolds)*

For wideband (> 5 GHz) T/R antennas, it is very difficult to fabricate low cost, low loss electronic delay lines for multi-octave TTD.



Electronic bi-directional delay lines are OK up to C-band

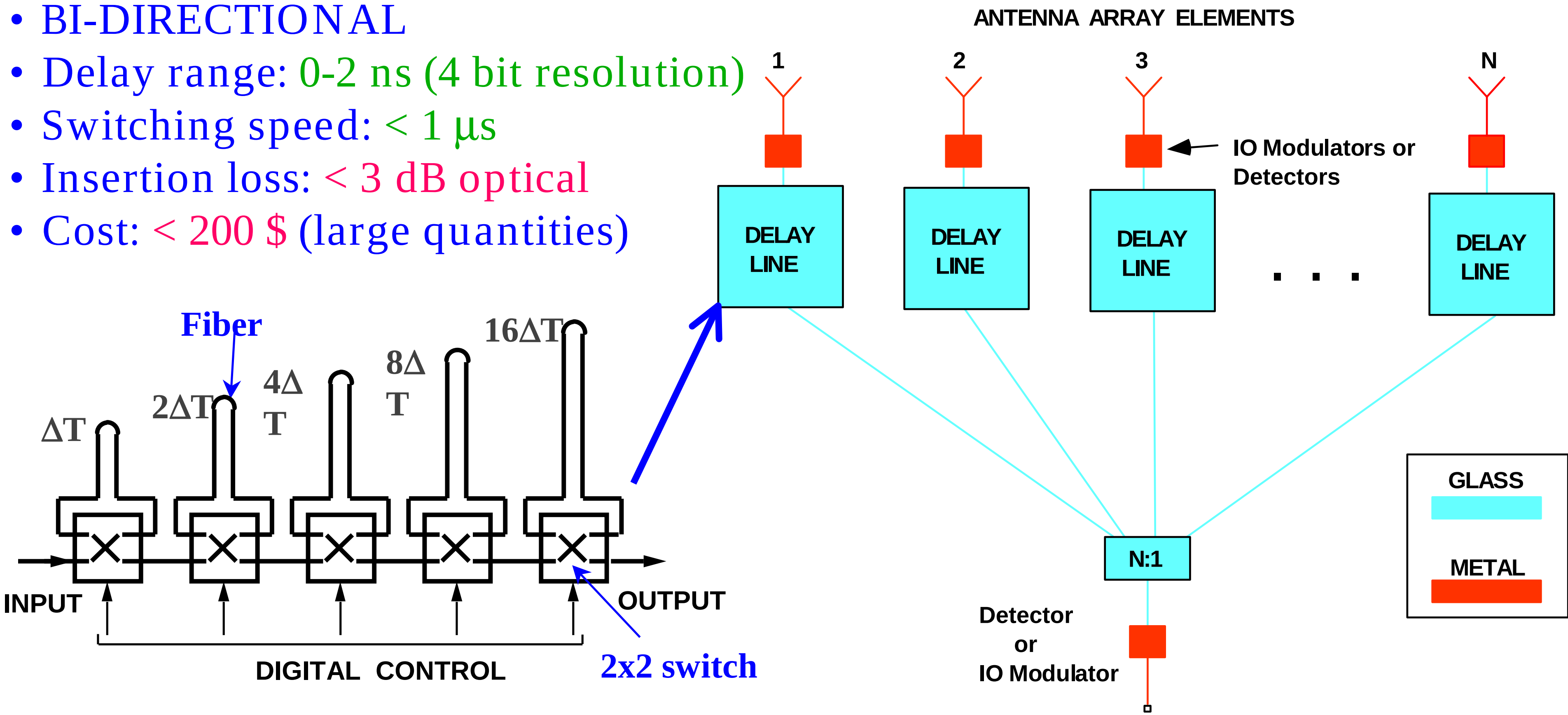




- 4-bits, 3.75 ns total delay, 50 ns switching speed,
- Cost: < $ 30 for moderate quantities (switch cost $ 7 for small quantities)

Need: *Low loss optical delay lines (analog RF manifolds)*

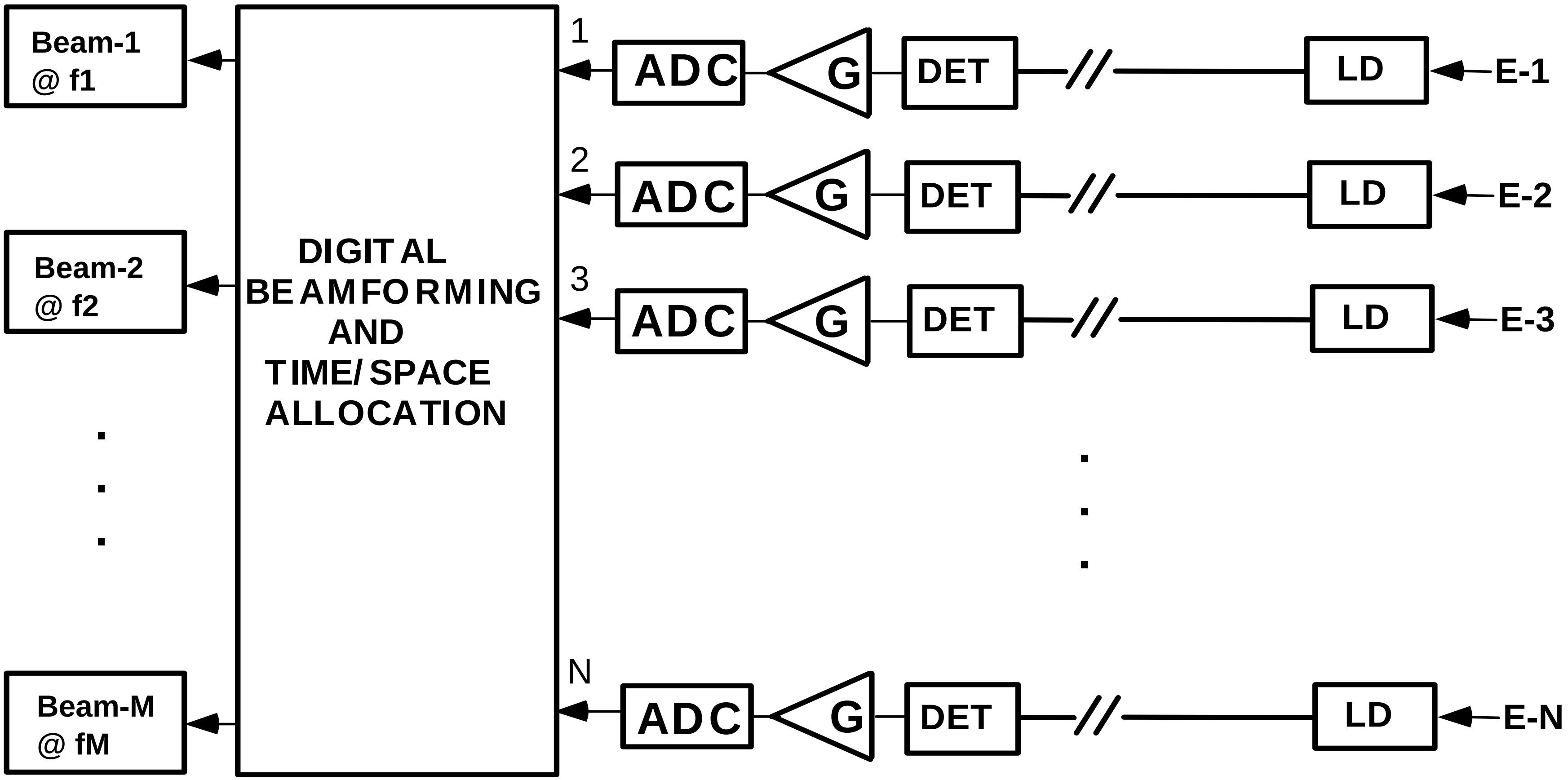
- BI-DIRECTIONAL
- Delay range: 0-2 ns (4 bit resolution)
- Switching speed: < 1 µs
- Insertion loss: < 3 dB optical
- Cost: < 200 $ (large quantities)



- Optical analog manifolds are needed for wideband transmit applications
- Can be used for "some" wideband receive applications

Need: *Low loss optical delay lines (DBF/RF manifolds)*

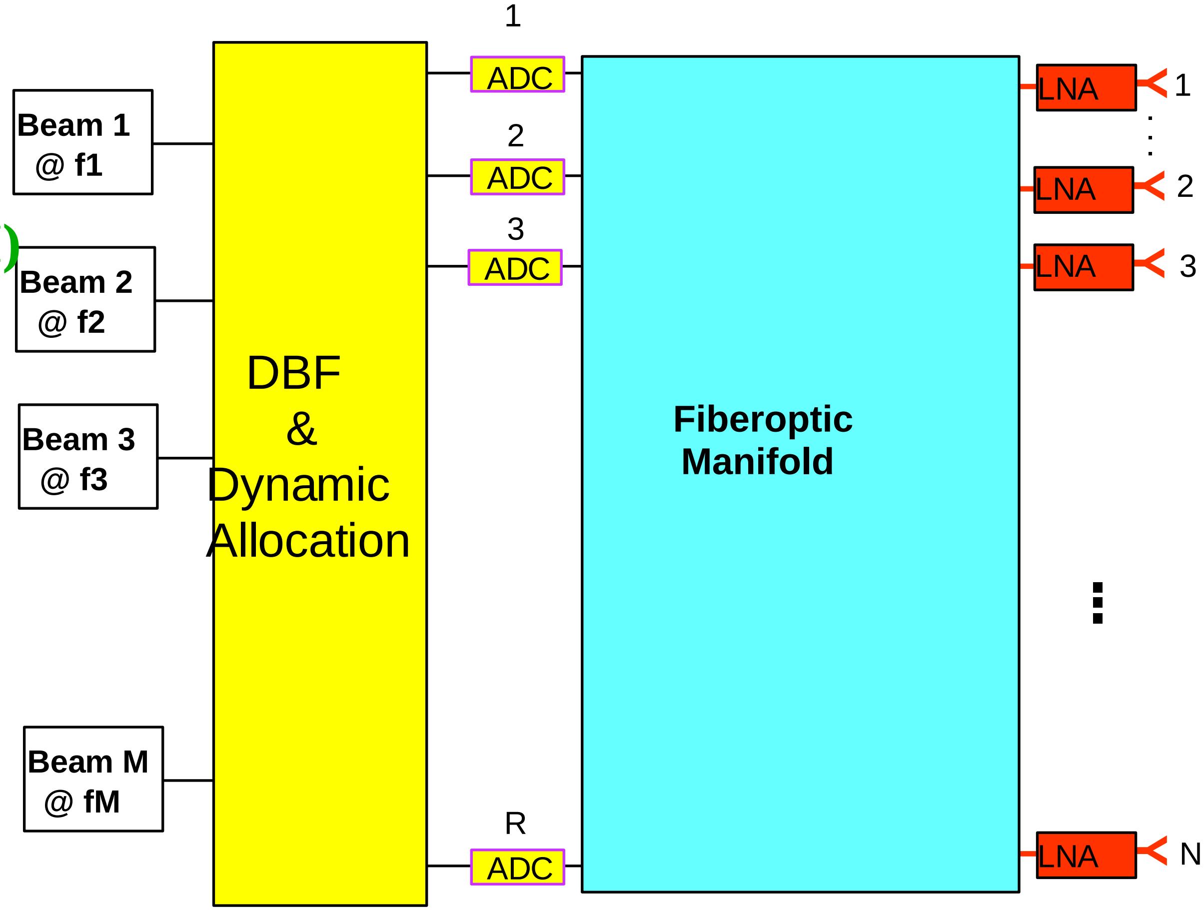
Wideband DBF manifold architecture



For DBF, STAP algorithms require ~ N^3 digital computations

Need: *Low loss optical delay lines (DBF/RF manifolds)*

- **DBF forms M beams from R Manifolds (N>R>M)**



- **ADCs needed: R not M**

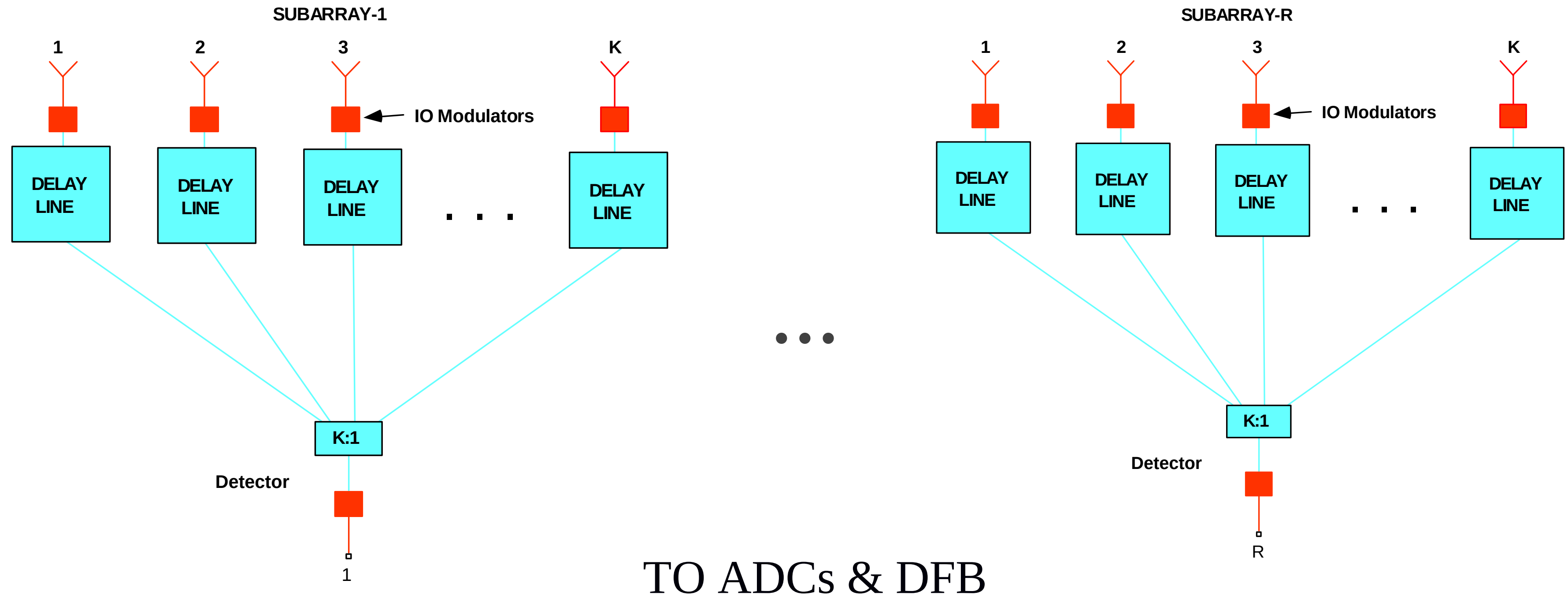
- **Less digital computation:**

<u>Example:</u> STAP with N=1000, R=50, M=10

No FO manifold: 10×1000^3 computations

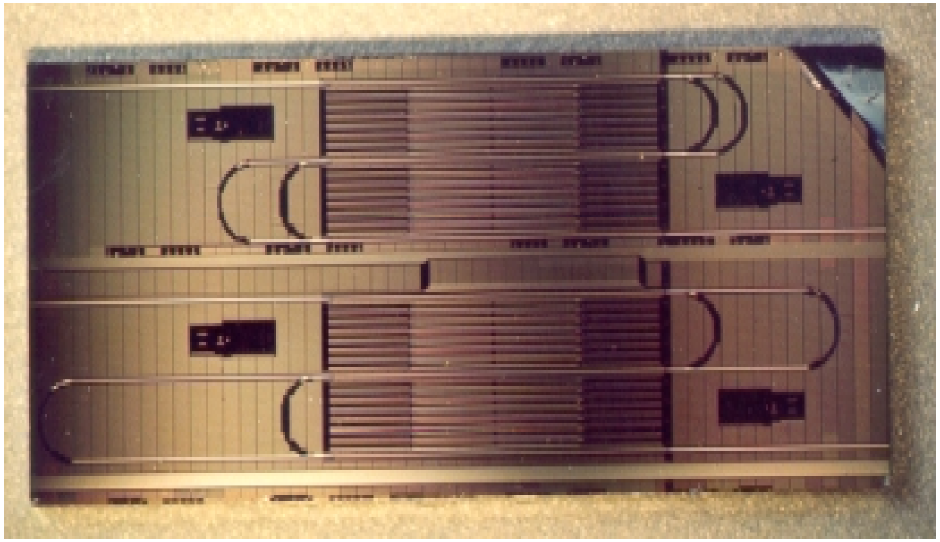
With FO manifold: 10×50^3 computations (8×10^3 LESS !!!)

Need: *Low loss optical delay lines (DBF/RF manifolds)*



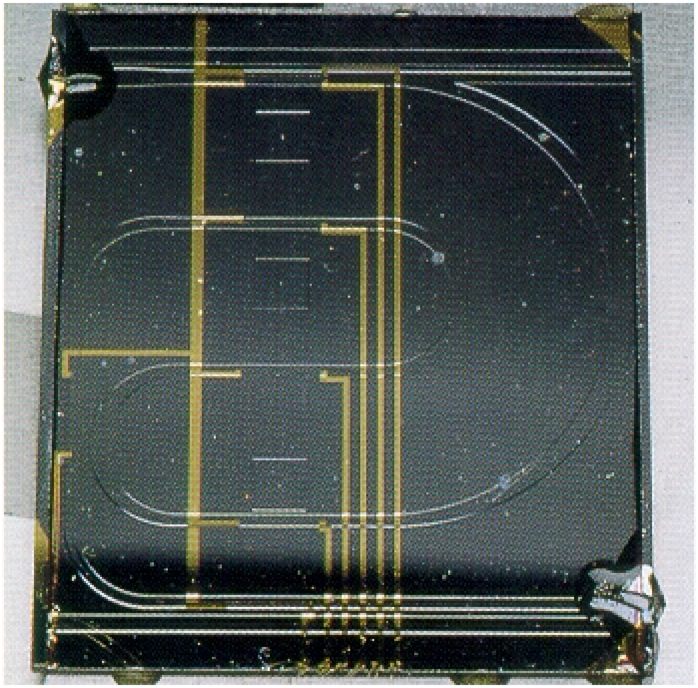
- Sub-array level analog optical manifolds will be needed for many current and future DFB applications
- Key element needed is a low cost, programmable delay line (4 bits OK)

Binary Photonic Delay Line: *Examples of previous work*



Honeywell 3-bit, Integrated Optical BIFODEL in GaAs
Delays: 250, 176, 83 ps, Size:25x12.5x1 mm

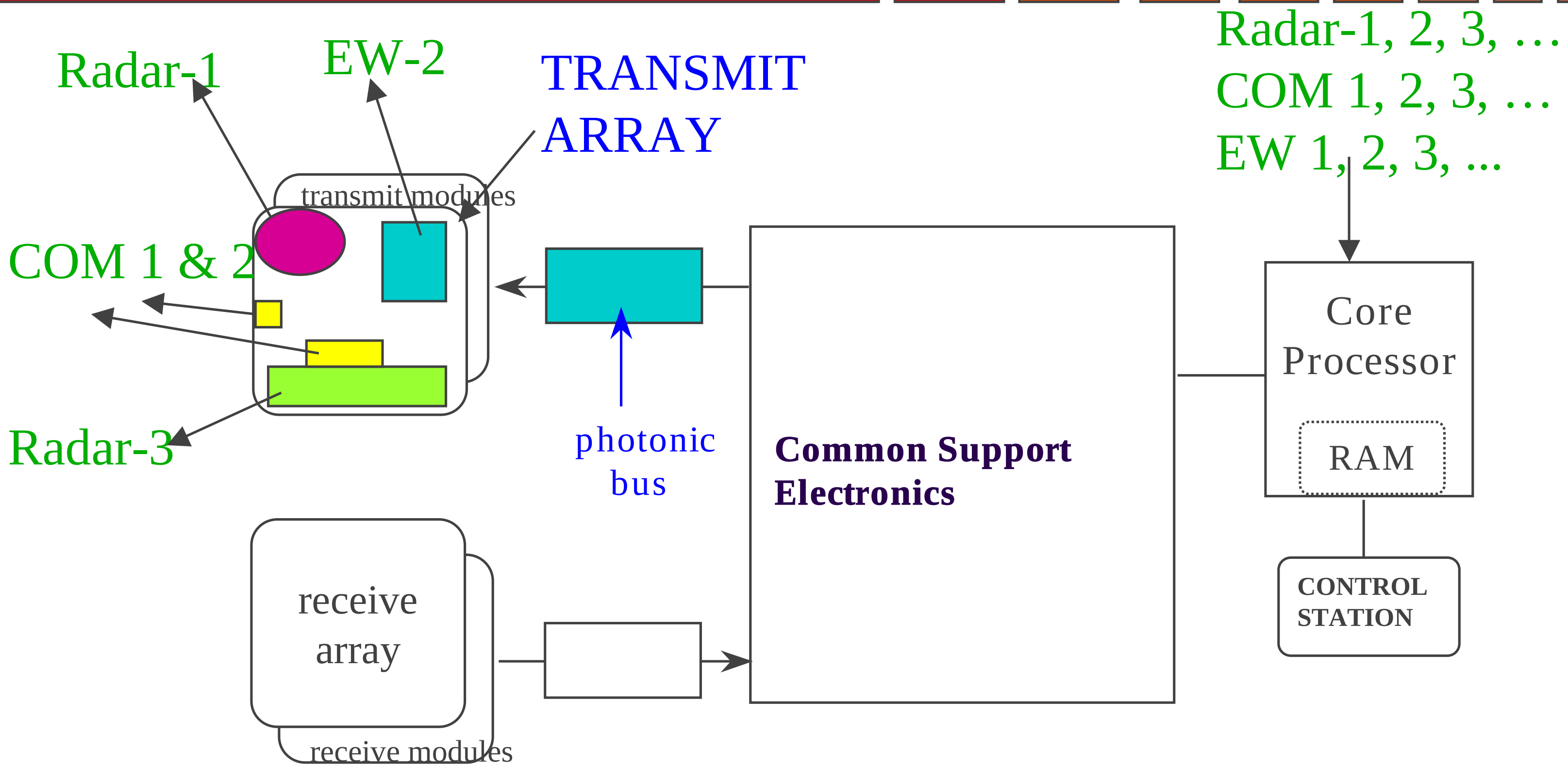
- Loss= 16.1 dB for 3 bits



NOI 5-bit, Integrated Optical BIFODEL in Silica
Total delay is ~ 1 ns (20 cm path)

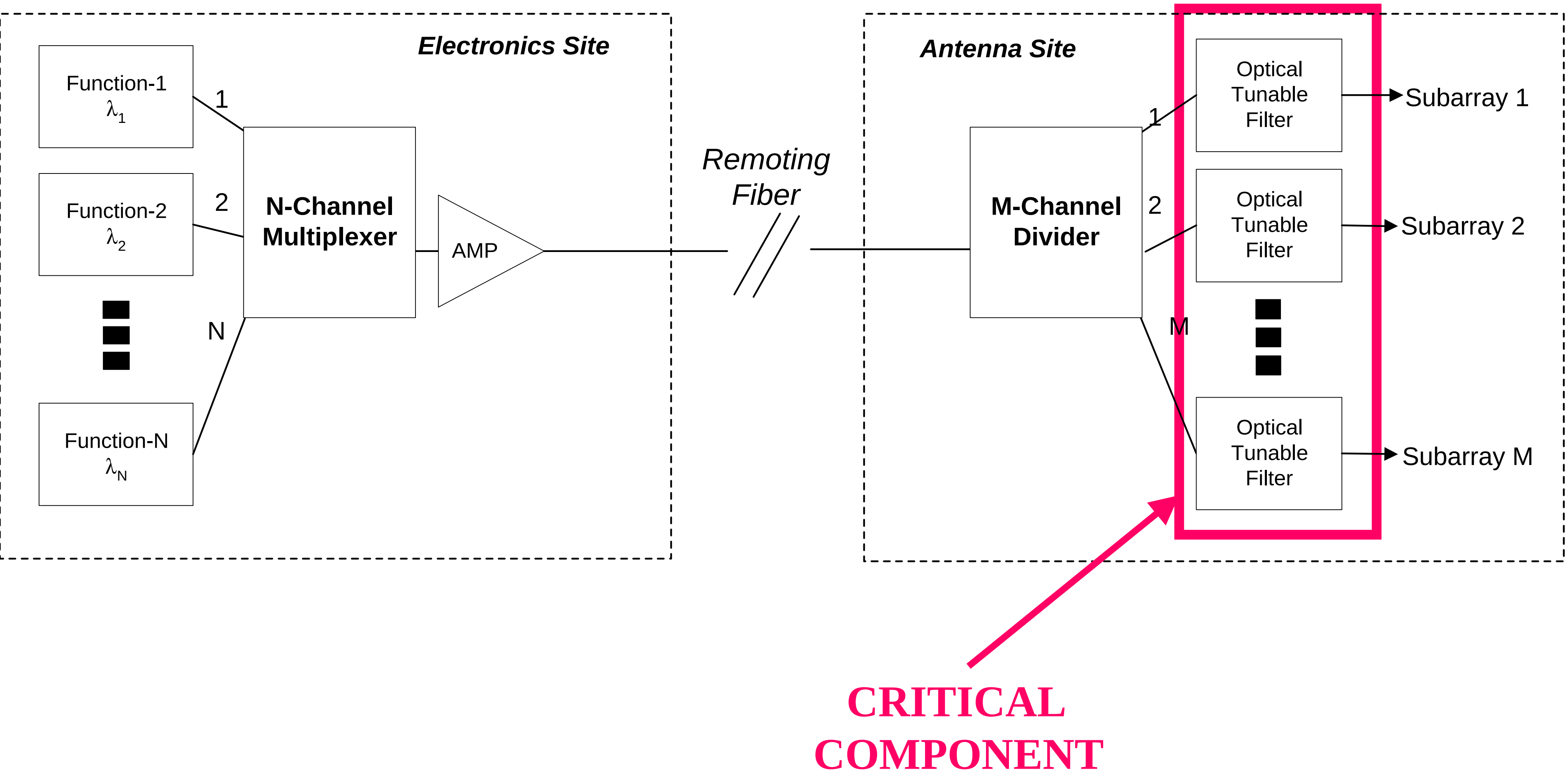
- Loss= 20 dB for 5 bits

Navy AMRFS Architecture

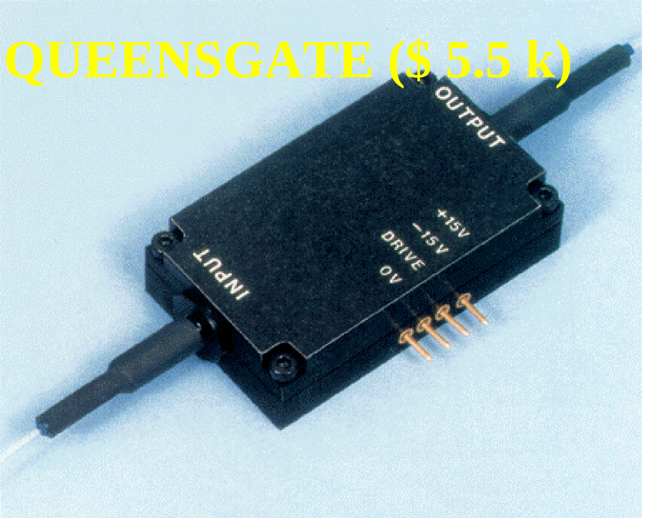


Effective dynamic allocation of wideband multifunction apertures and transmit/receive resources requires an advanced RF interconnection network, with programmable *broadcast*, *multicast*, and *narrowcast* capability.

Need: *Optical tunable filters*



Need: *Optical tunable filters*



BW: 29.6 nm (vs 14 nm of bus)
3 dB Op. BW: 0.15 nm (18.75 GHz)
IL: 3.0 dB, Speed: 50 nm/ms

BW: 30 nm (vs 14 nm of bus)
0.5 dB Op. BW: 0.6 nm (75 GHz)
IL: 1.0 dB, Speed: Manual

- **COTS filters drift, are lossy, and affect the system Phase Noise**
- **Need: low cost stable tunable filter bank (size is not an issue)**

(1 ms speed, 0.5-dB optical BW of 0.6 nm, 1-2 dB loss)