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Focal Plane Array Concept for ALMA 2030

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Overview (1)

Desires for Focal Plane Array (FPA) used within ALMA:

- Modularity vs. Integration trade-off:
  - → Which parts are likely repeatable and can be integrated?
  - → Which parts are variable, prone to failure, or require tweaking?
  - → Trade-off: 'N' pieces ⇔ full integration

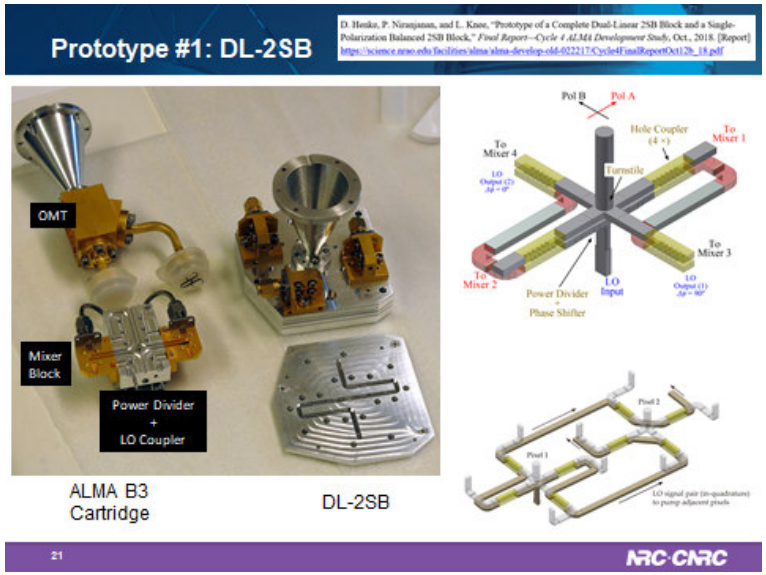
- Same performance as single-pixel receivers:
  - → Dual-linear, 2SB
  - → Ideally, share same components with single-pixel receiver (e.g., mixer block)

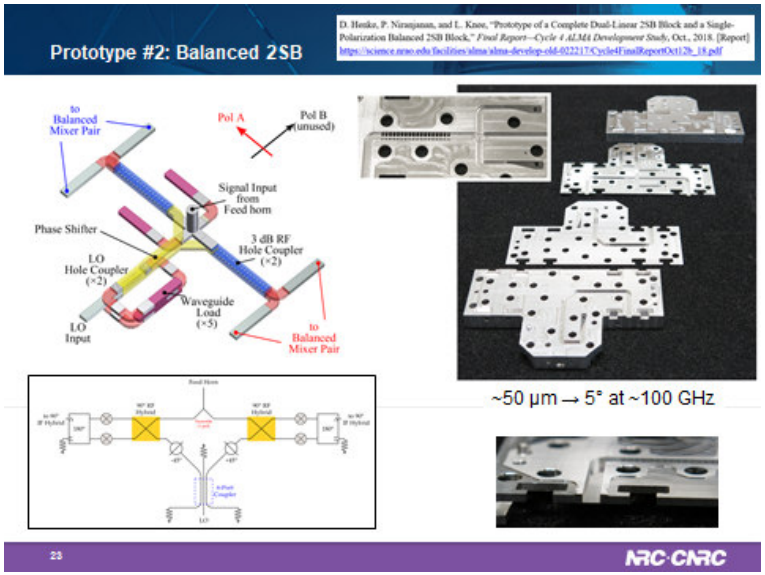
- Use components with isolation to reduce pixel-to-pixel leakage
- Size
- Split-block used for mixer block so that conventional chip mounting can be used
  - → Serviceable (chip replacement)
  - → Mixer block de-coupled within array (mixer block replacement)

Lessons Learned: Cycle 4 Study

Evaluated OMT-integrated, platelet-type architectures for future array implementation

- ✘ Using the turnstile as a power divider for 2SB didn't work – need isolation!
- ✓ Platelet implementation, integrating OMT
- ✓ Hole coupler for LO coupling and LO re-use worked
- ✓ Relative machining precision to give phase and amplitude balance

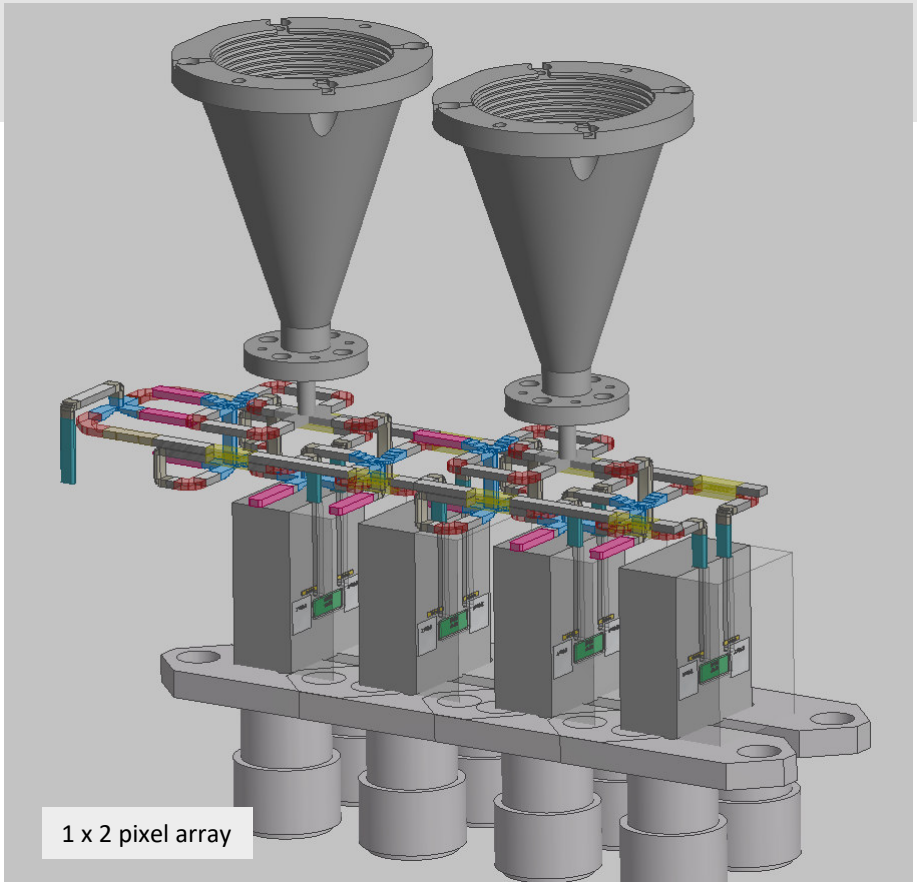




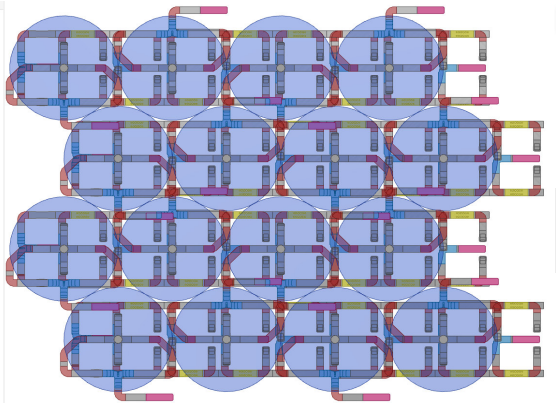
D. Henke, P. Niranjanan, and L. Knee, "Prototype of a Complete Dual-Linear 2SB Block and a Single-Polarization Balanced 2SB Block," *Final Report—Cycle 4 ALMA Development Study*, Oct., 2018. [Report]
https://science.nrao.edu/facilities/alma/alma-develop-old-022217/Cycle4FinalReportOct12b_18.pdf

Design Concept

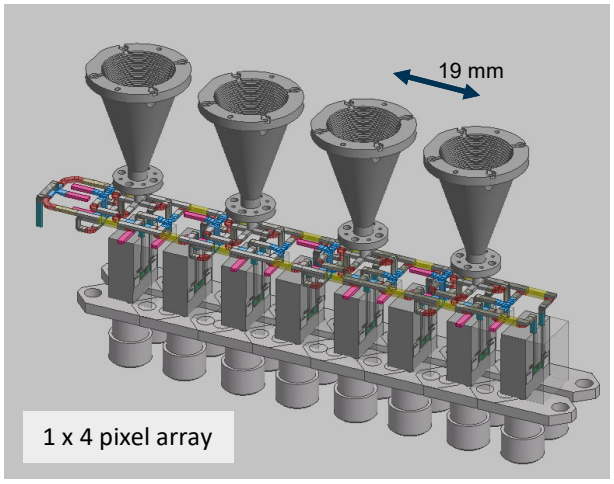
- **DL2SB “unit cell”**



- Integrate OMT, power dividers, and LO coupling
- Mixer blocks are separate
- Platelet assembly
- LO distributed along the array line

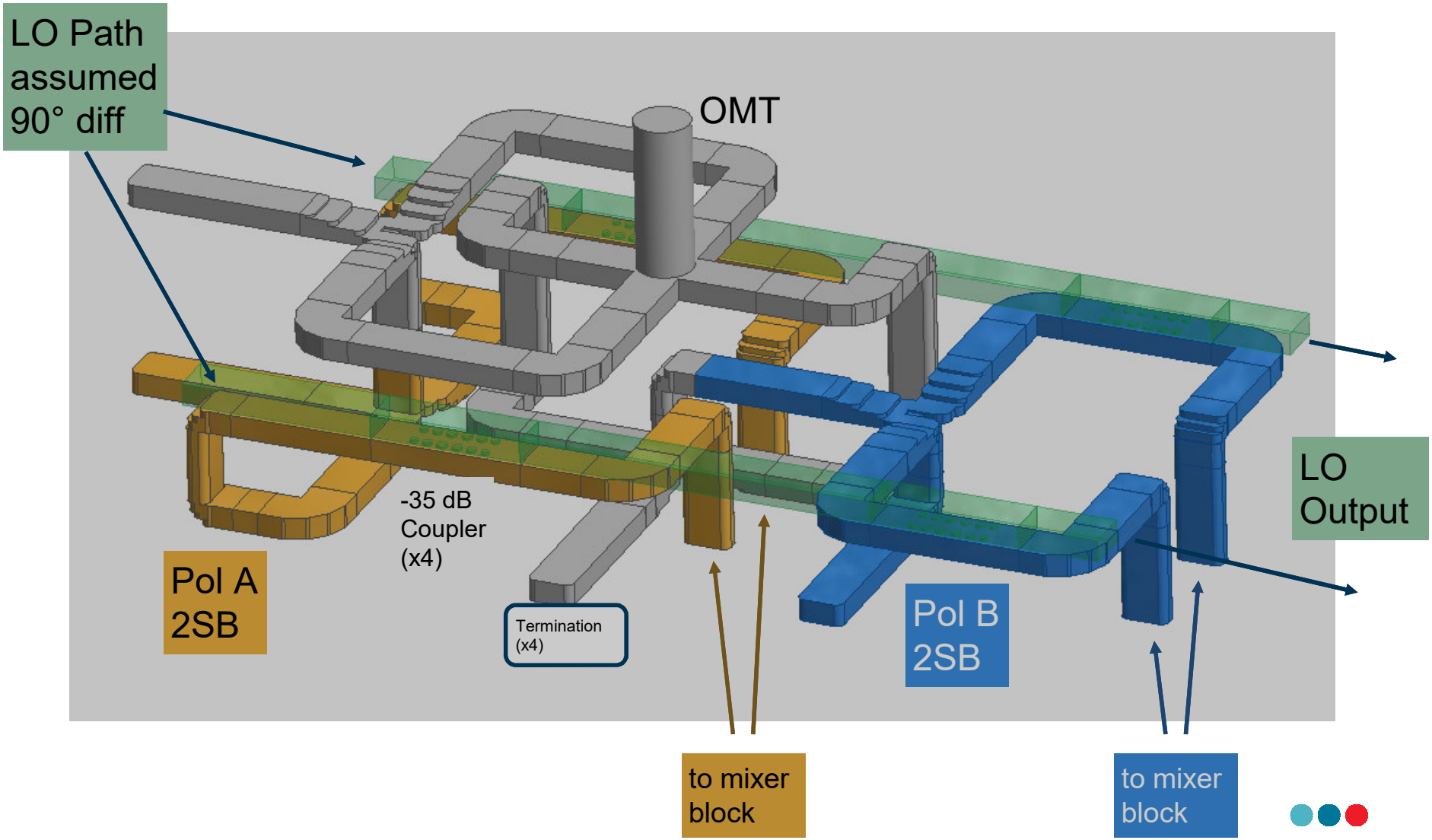


Example:
4 x 4 pixel array



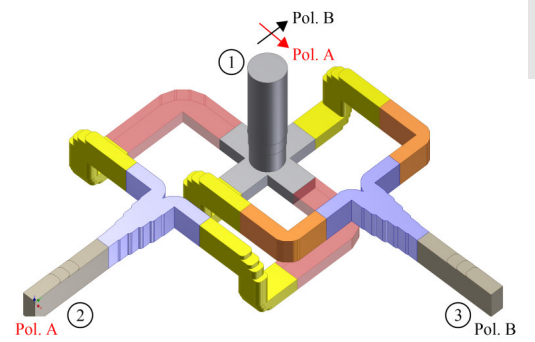
“Unit Cell” OMT + 2SB

Comprising: (1) OMT, (2) power dividers, and (3) LO path

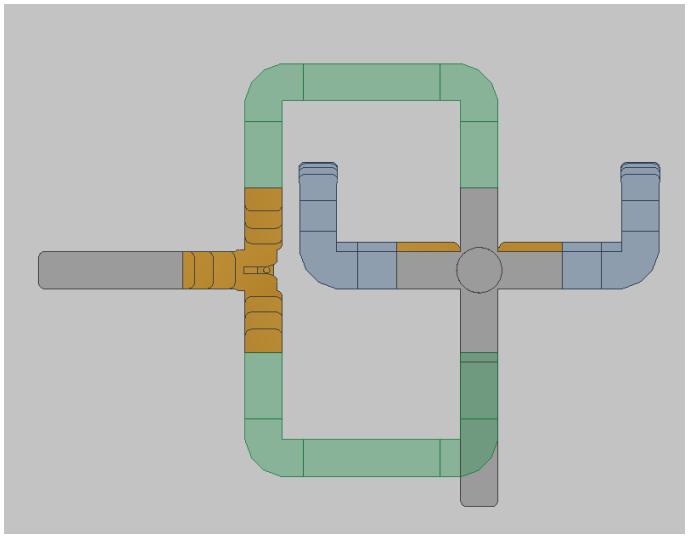


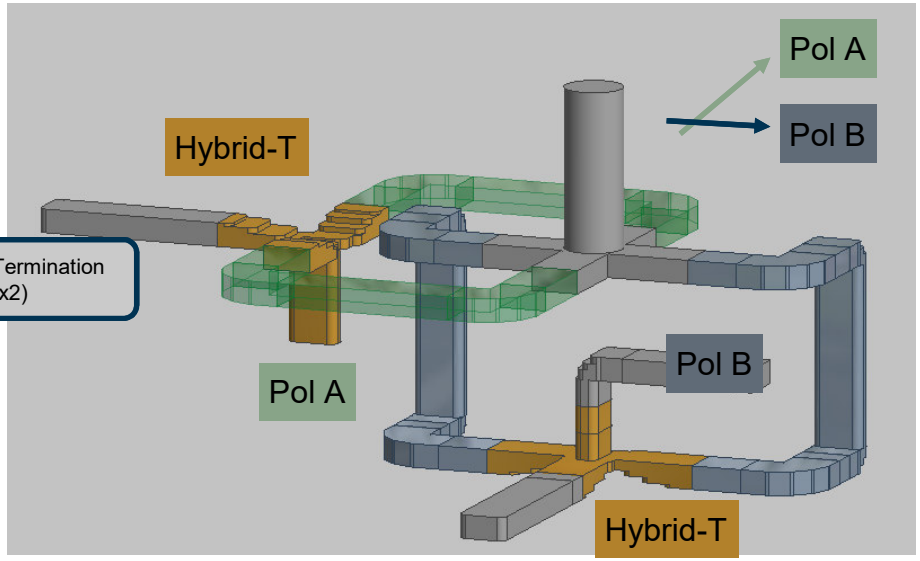
“Unit Cell”: OMT Section

- **Turnstile**
- **Branch combiners are <u>hybrid-Ts</u> (replacing simple T-junction)**
  - **Absorber used to terminate 4th port**
- **Hybrid-T helps with layer misalignment**
- **Symmetric branches**



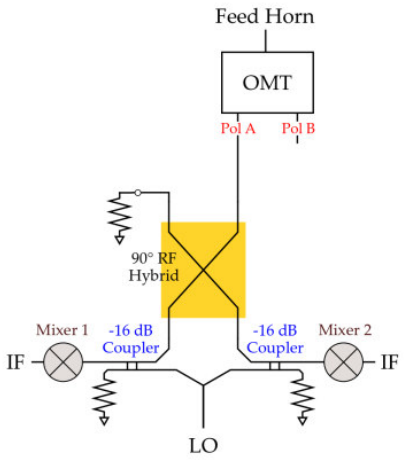
(Turnstile OMT with T or Y-junction)



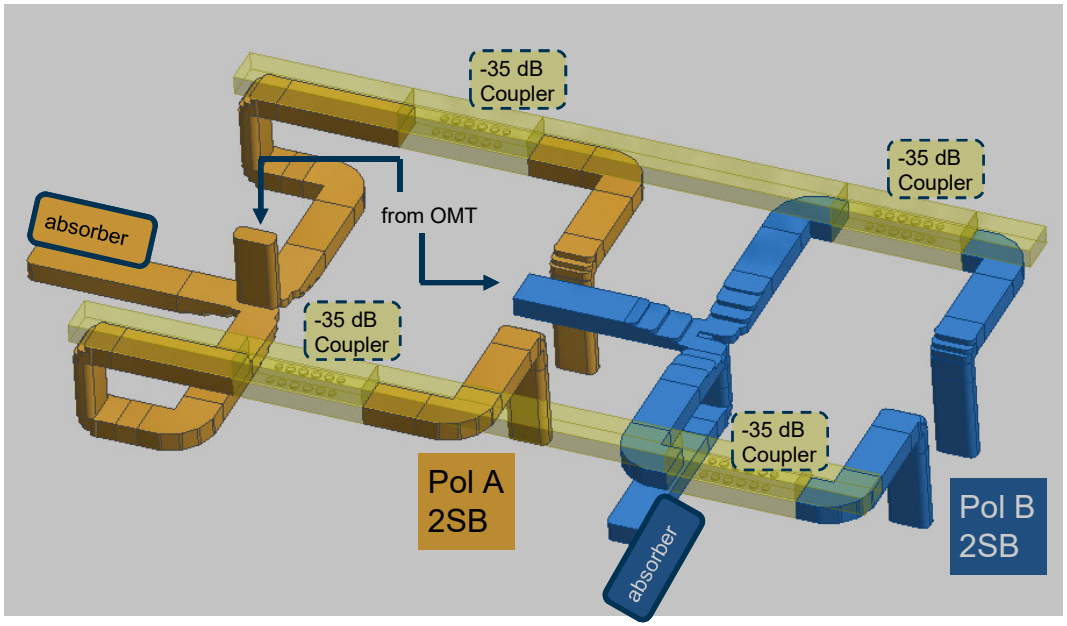


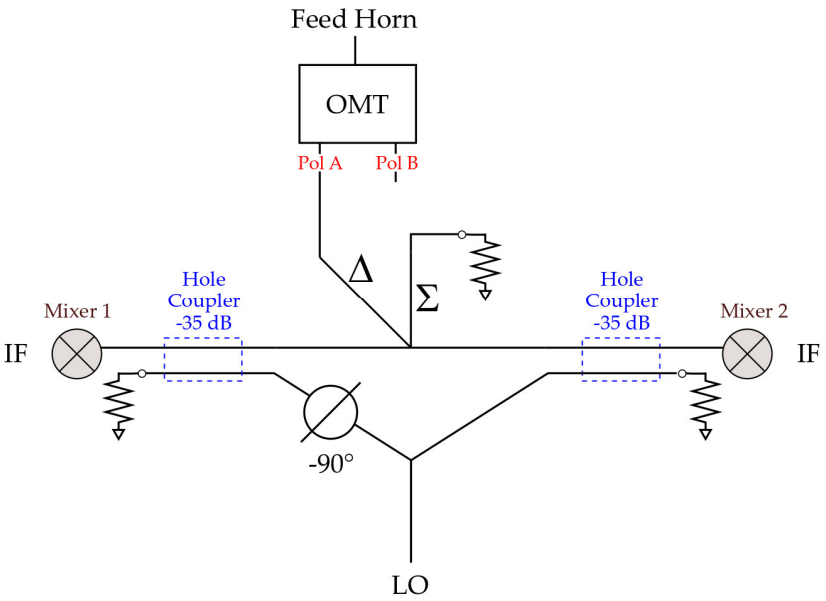
“Unit Cell”: Power Dividers for 2SB

- **Hybrid-Ts for power division to give isolation**
- **Mixers have high reflection, need to use 4-port hybrid as in current cartridge designs. Branchline couplers suitable for split-block, hybrid-T suitable for platelet.**
- **Pol A splits through diff port**
- **Pol B splits through sum port**
- **LO added in-quadrature, RF 0° or 180°**



ALMA B3 Cartridge





"Unit Cell": LO Path

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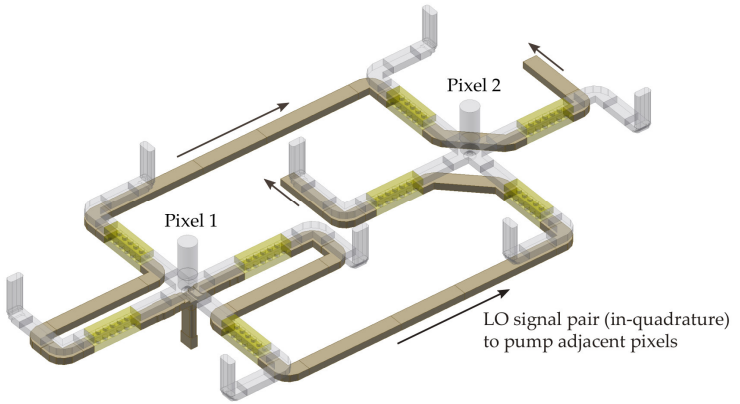
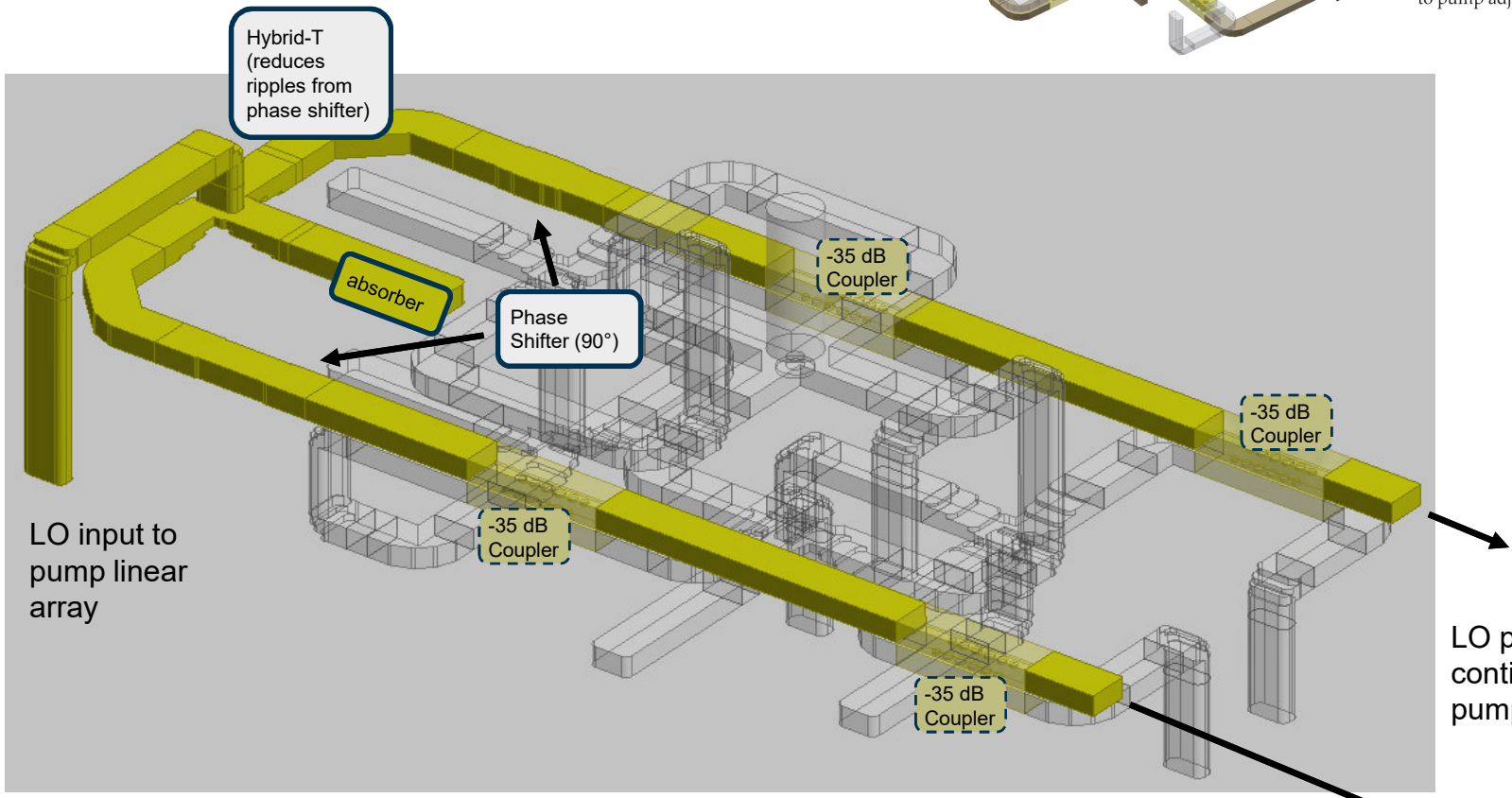
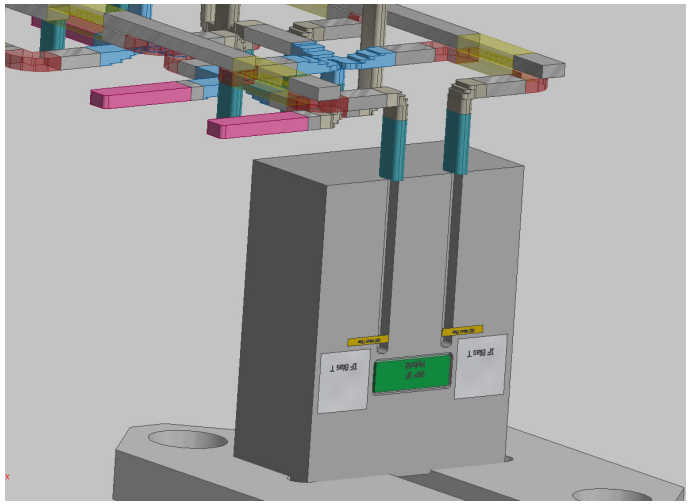
- **LO added in-quadrature, RF 0° or 180°**
- **Hole couplers were used to pump 4 mixers in Cycle 4 study prototype.**

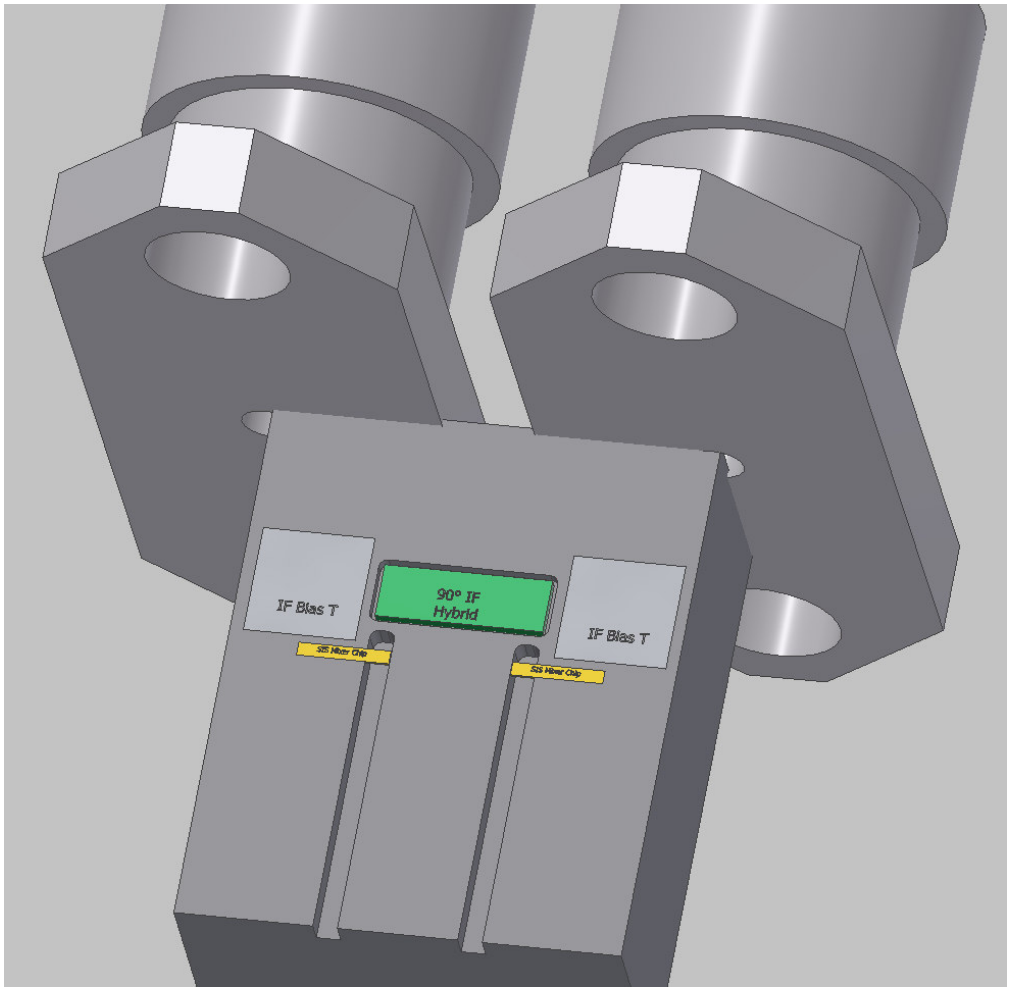




Mixer Blocks with IF Coupler

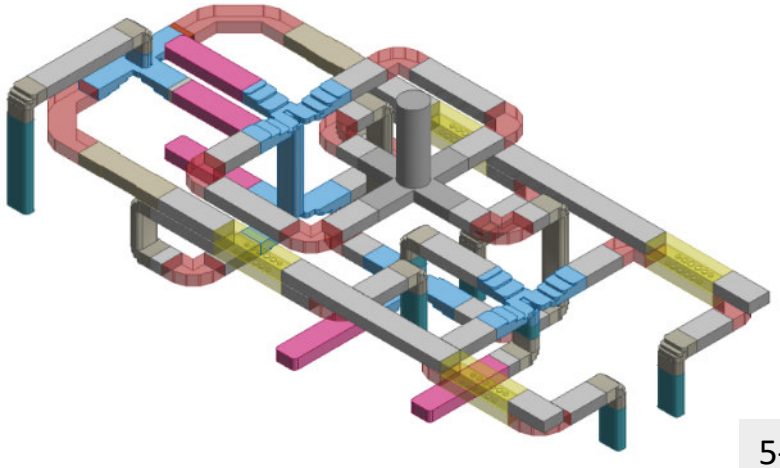
- Mixer blocks are split-block to facilitate chip mounting
- No integrated RF couplers (facilitates “simple” measurement of DSB mixers during qualification)
- Machining complexity is shifted away from mixer block
- Integrated IF hybrid and bias T
- Smaller SMP coax needed, but SMA shown for scale (shown here with respect to Band 6)

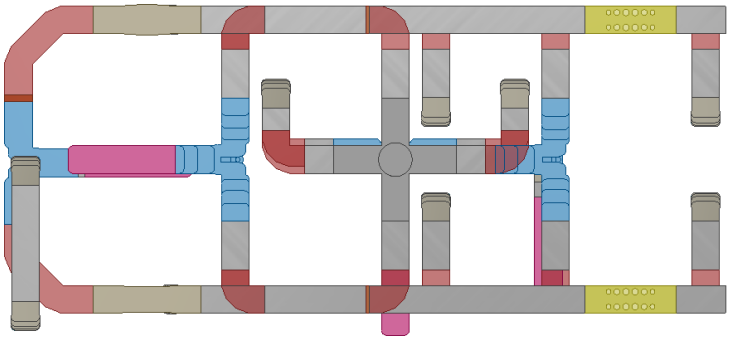




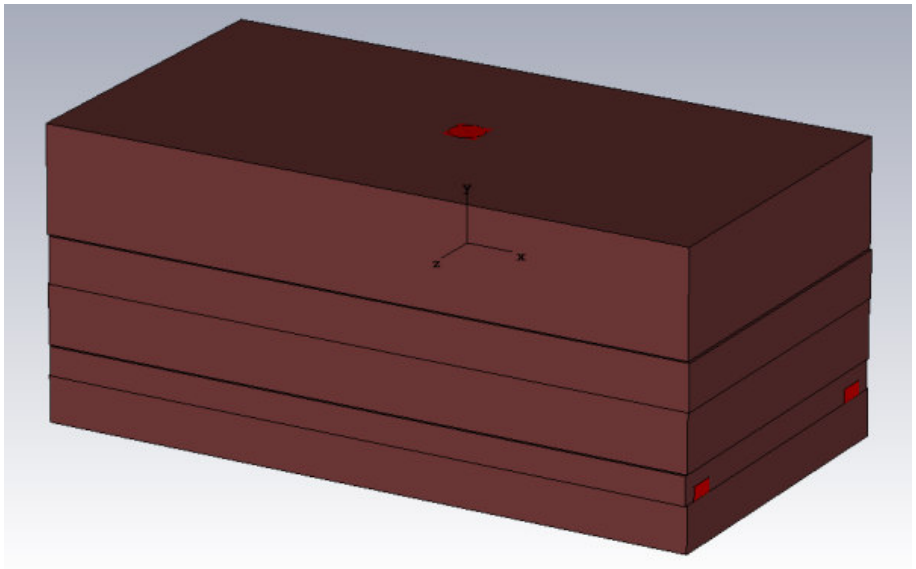
Implementation of DL2SB “Unit Cell” Block

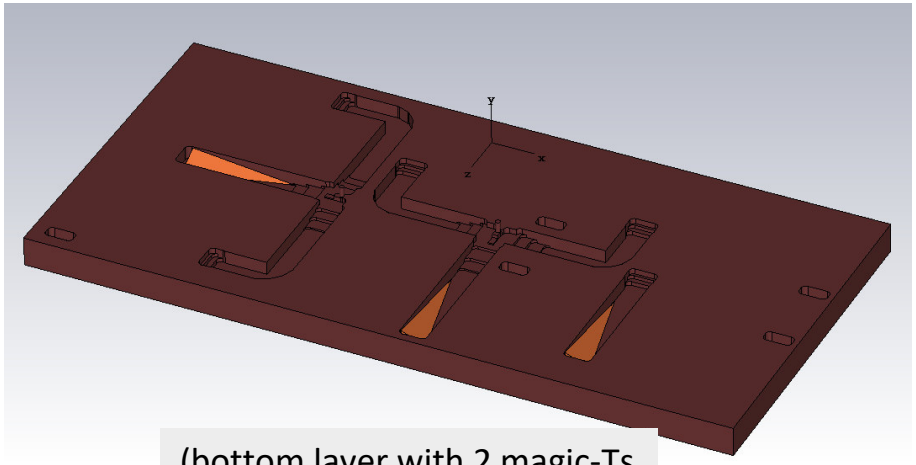
- **Platelet designs are naturally suited for arrays**





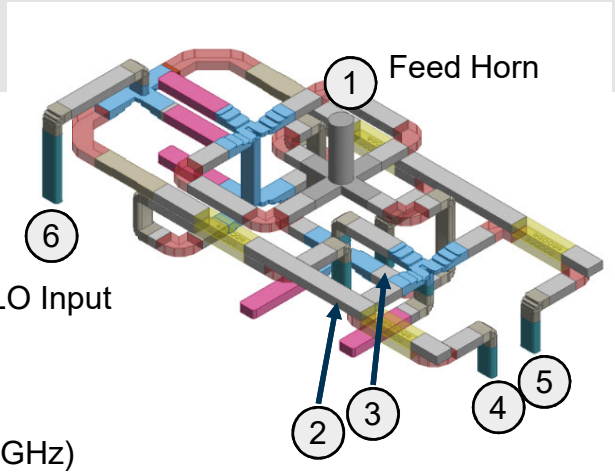
5-layer platelet design for a single-pixel

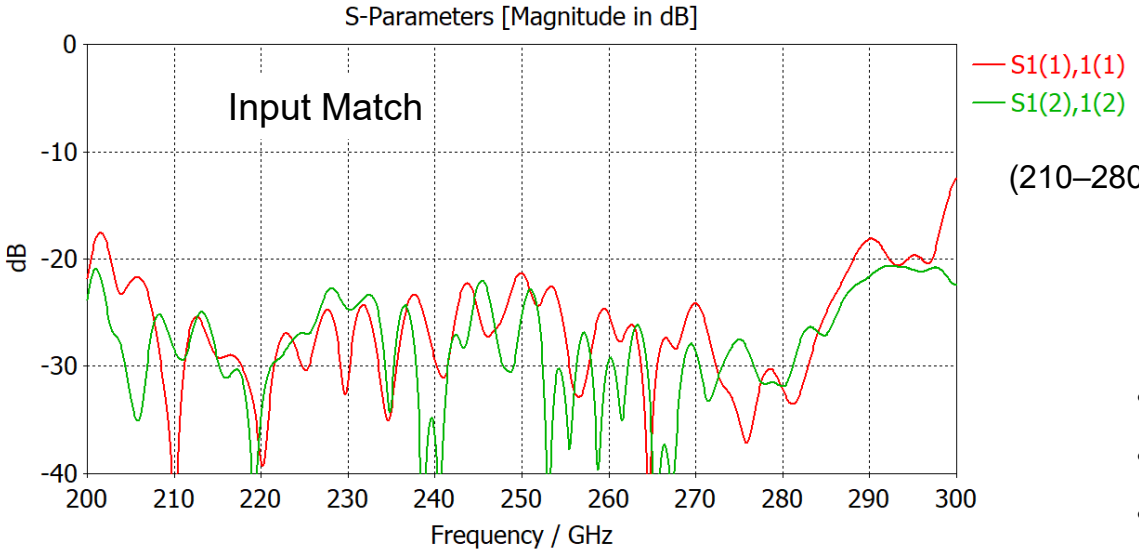




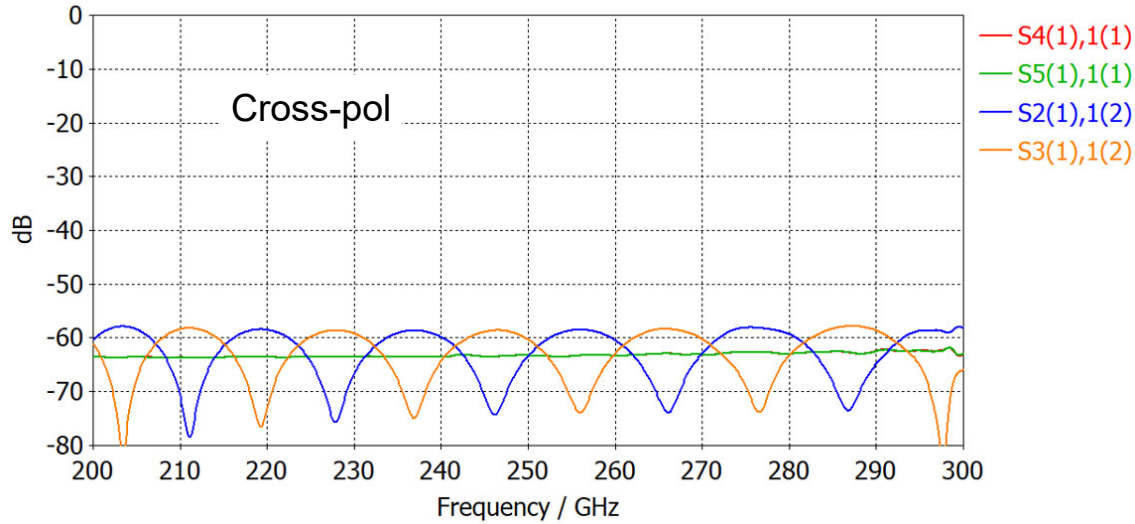
(bottom layer with 2 magic-Ts and 3 wedge absorbers)

“Unit Cell”: Simulations



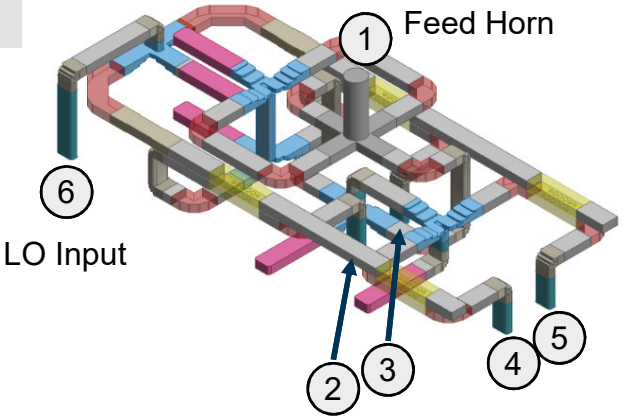


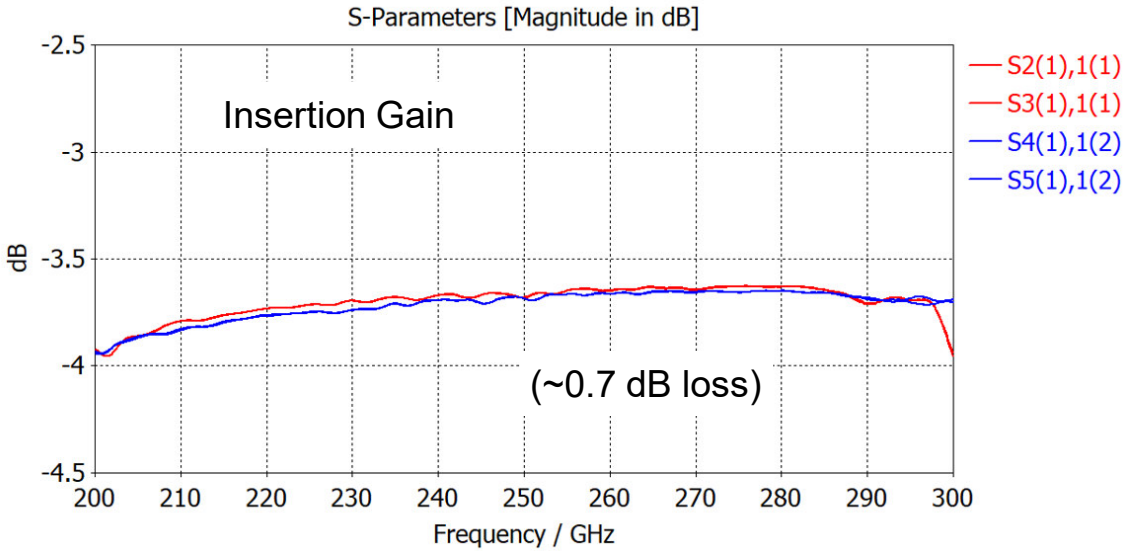
(210–280 GHz)

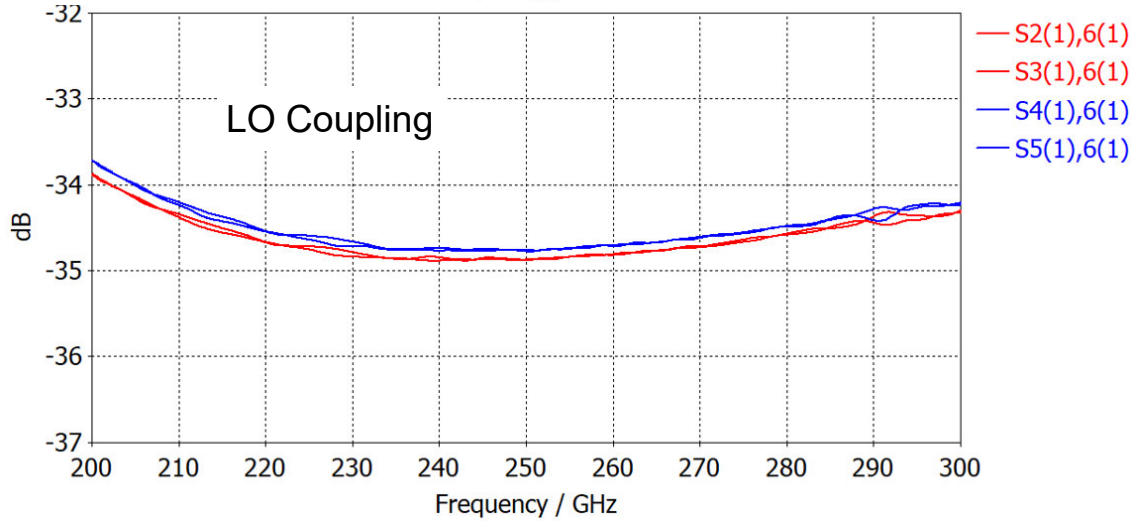


- S-parameter simulations from CST
- Metal conductivity is 5e7 S/m
- Complete response of entire network: OMT+2SB dividers

“Unit Cell”: Simulations







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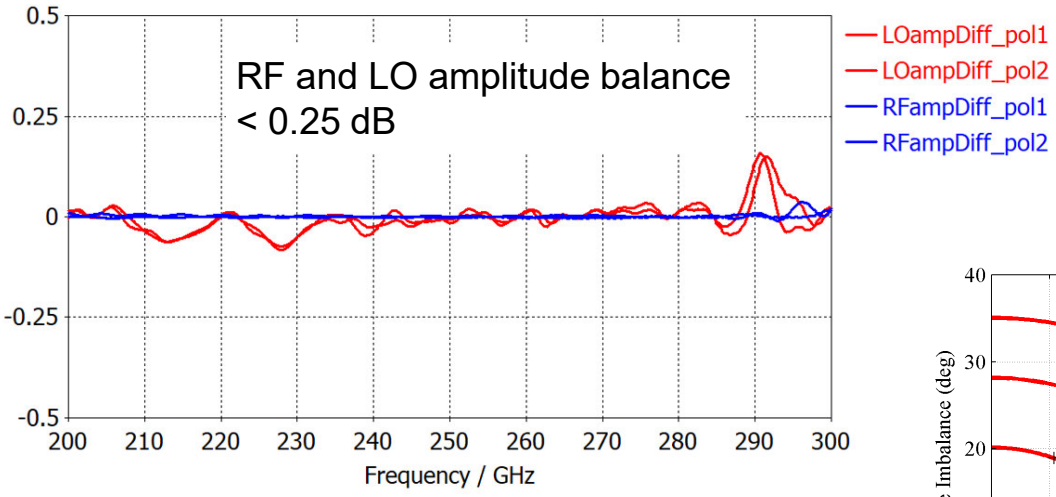
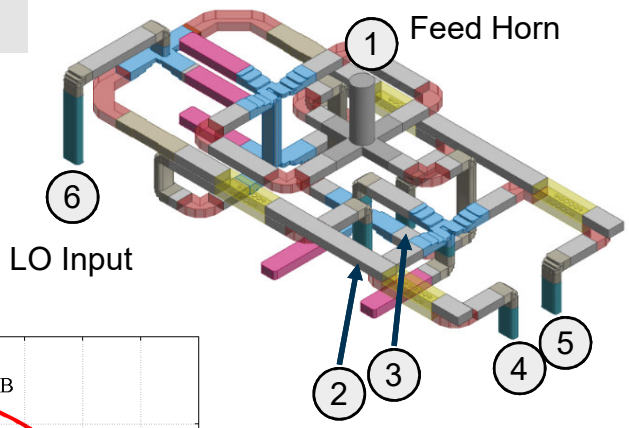
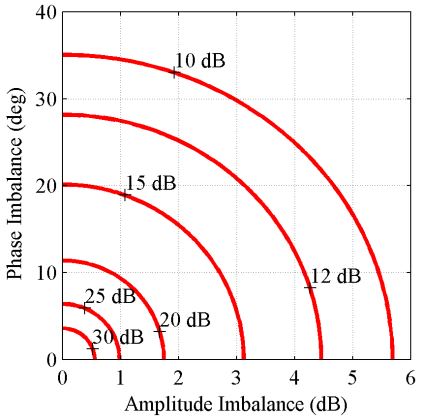
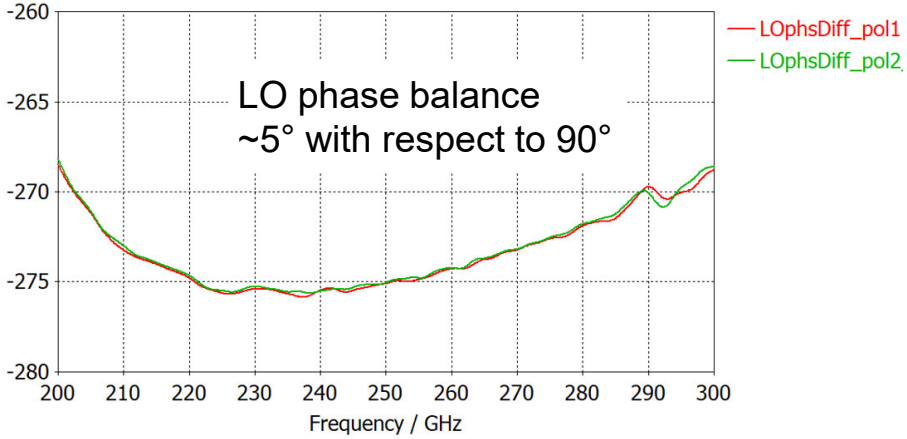


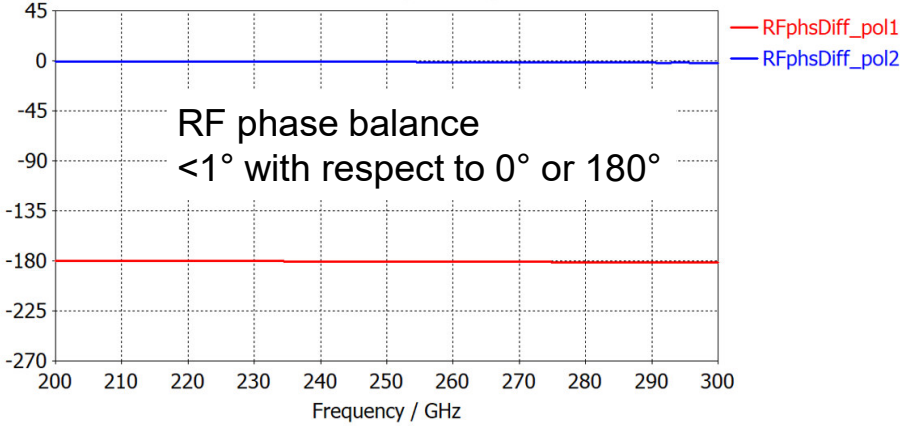


To mixer block pairs

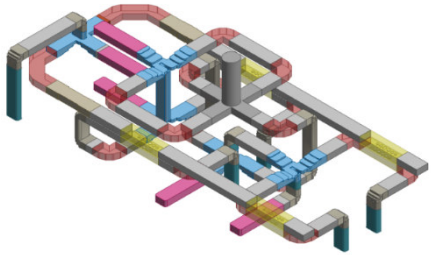


A. R. Kerr and S.-K. Pan, “Design of planar image-separating and balanced SIS mixers,” in *Proc. 7th Int. Symp. Space Terahertz Technol.*, Mar. 12–14, 1996, pp. 207–219.



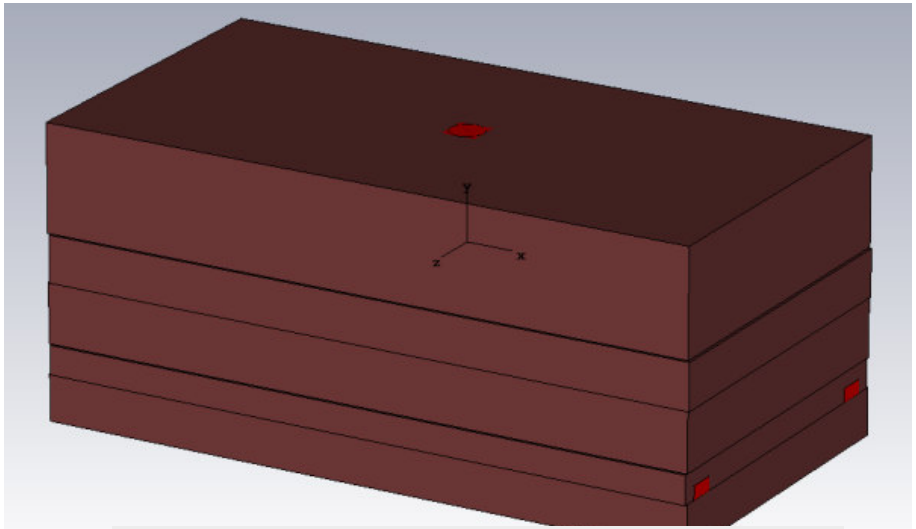


Misalignment in Platelet Stack-up



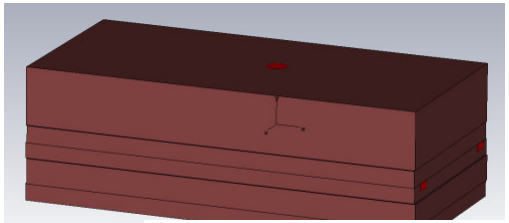
A common problem is block misalignment:

- Especially where multiple modes can propagate (e.g., circular or square waveguides…turnstile)
- Degrades balance
- Trapped energy/resonances
- Pixel-to-pixel leakage

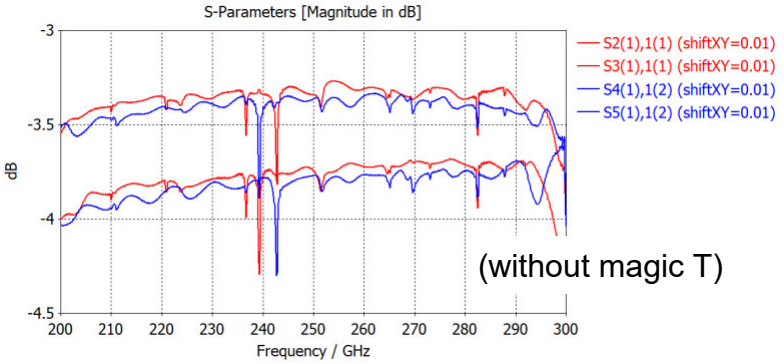


5-layer platelet design for a single-pixel block

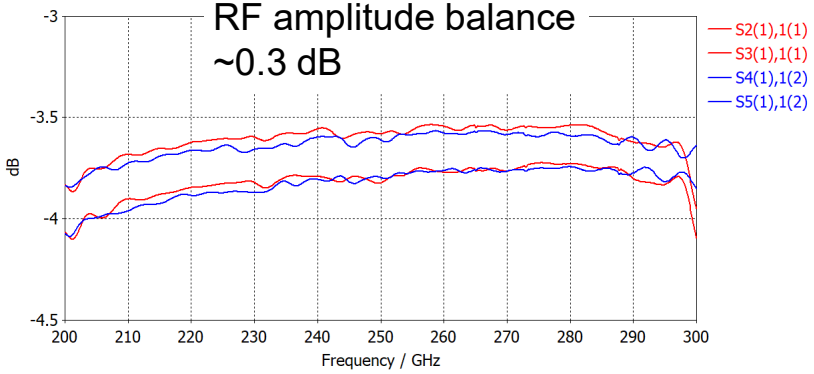
In CST, shifted 2nd and 4th pieces in both X and Y



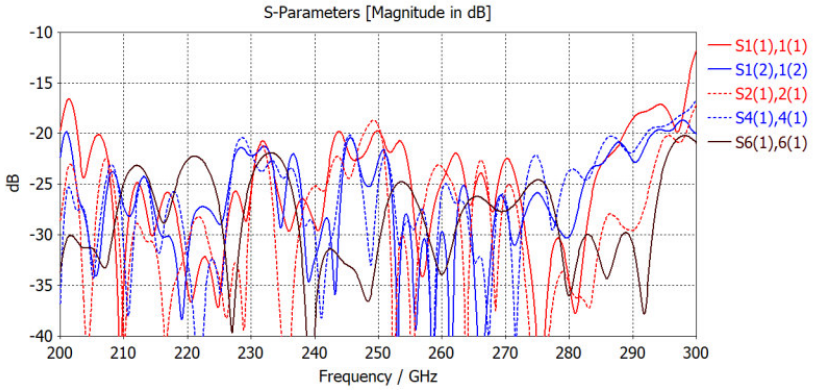
Effect of misaligning all layers

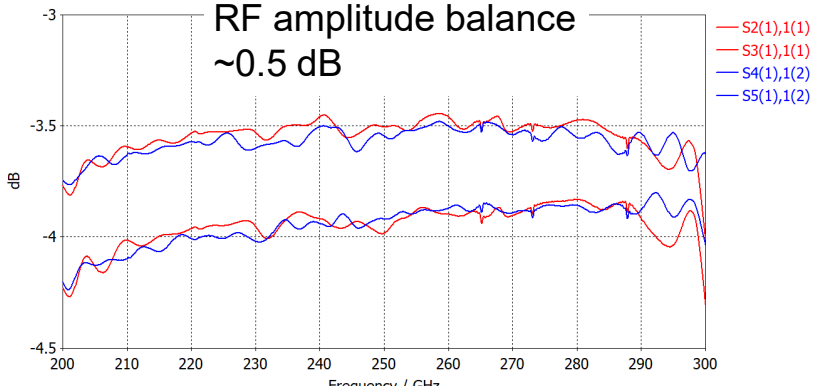


(without magic T)

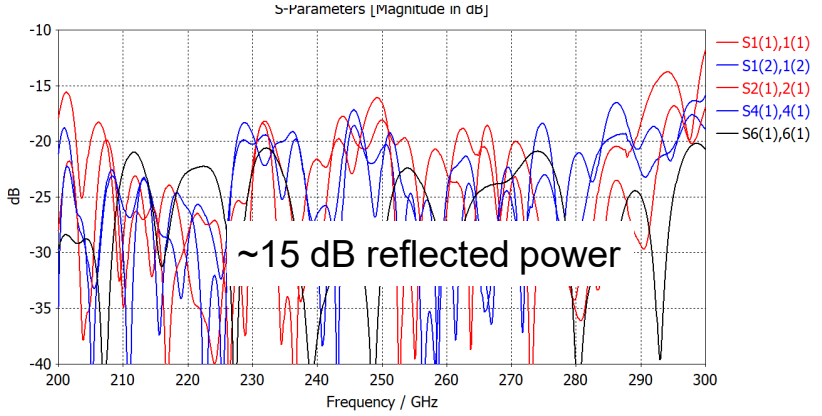


5 μm misalignment



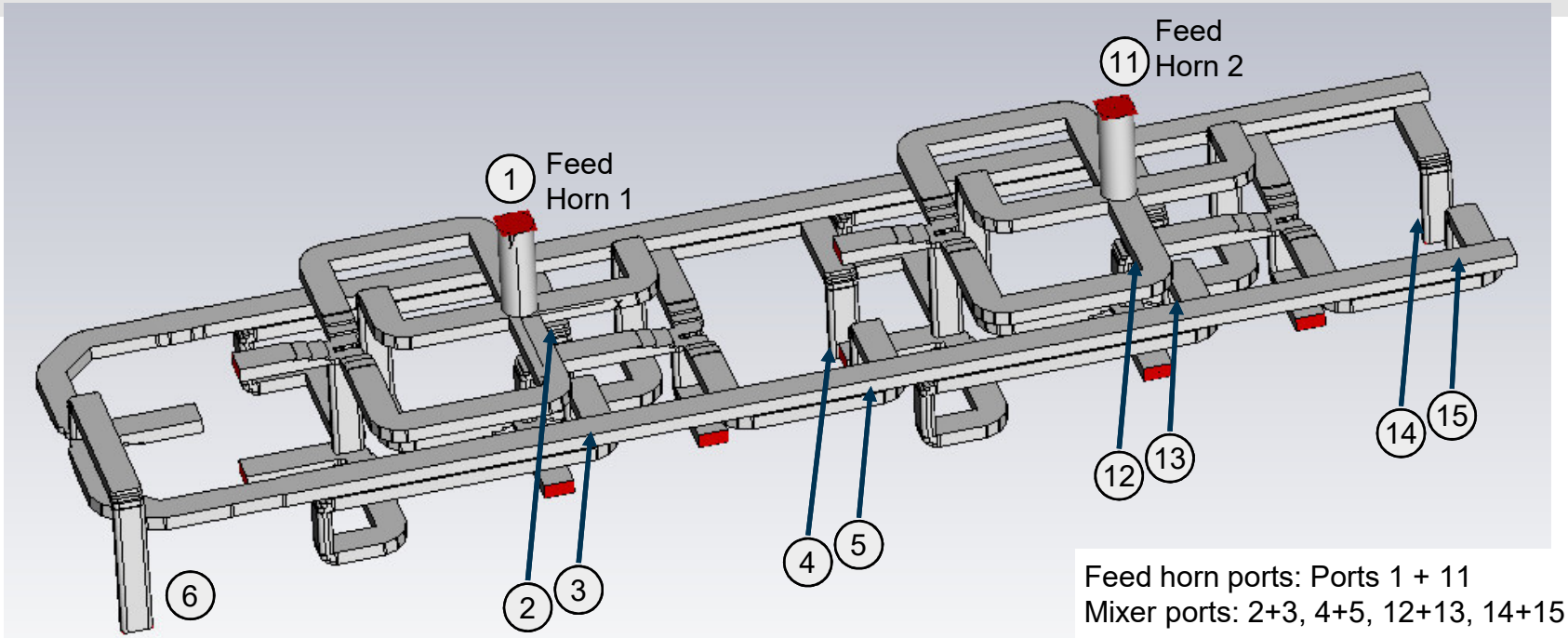


10 μm misalignment

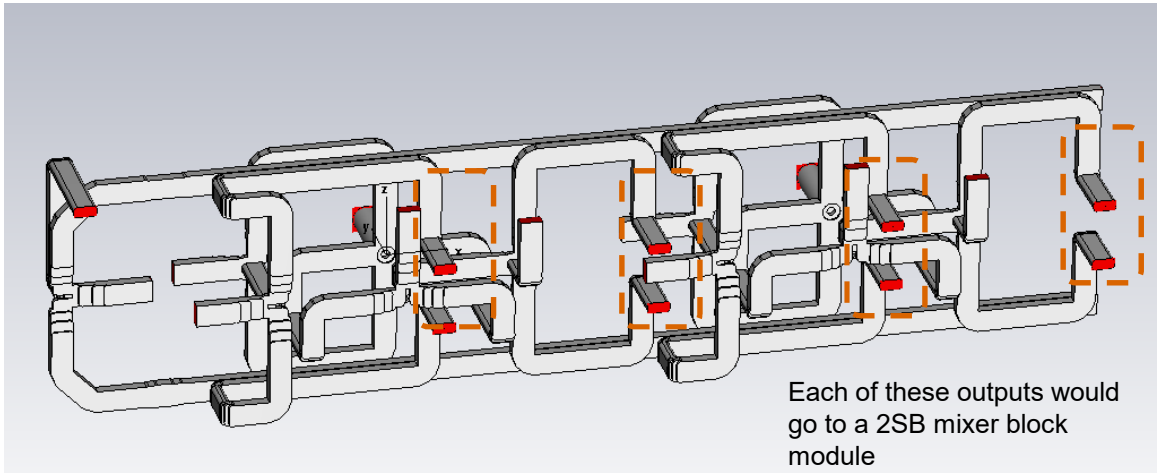


Integrated magic-Ts reduce spikes + trapped modes
Design should tolerate 5–10 μm of misalignment

2-Pixel Array

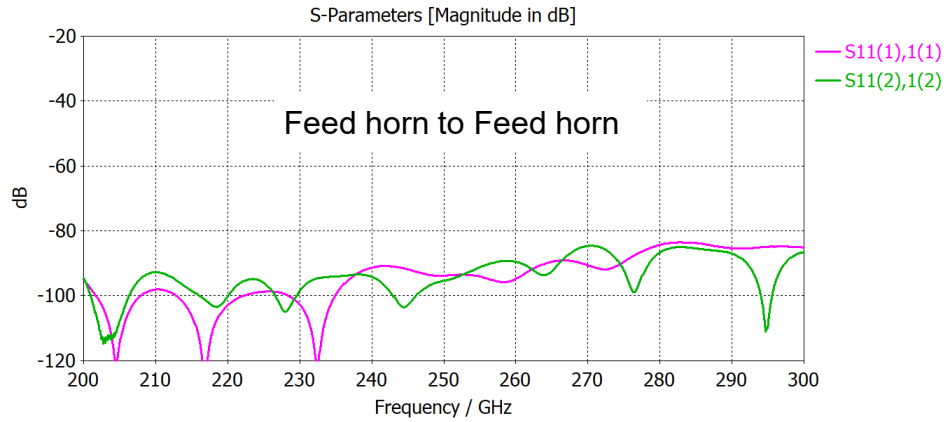


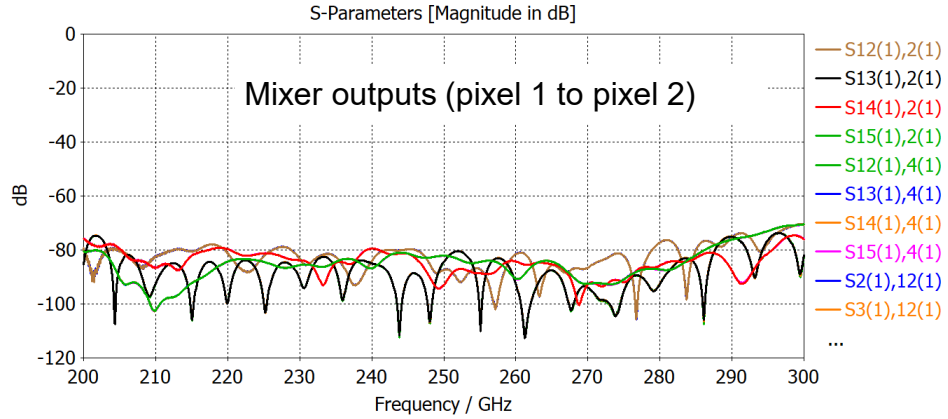
Feed horn ports: Ports 1 + 11
Mixer ports: 2+3, 4+5, 12+13, 14+15

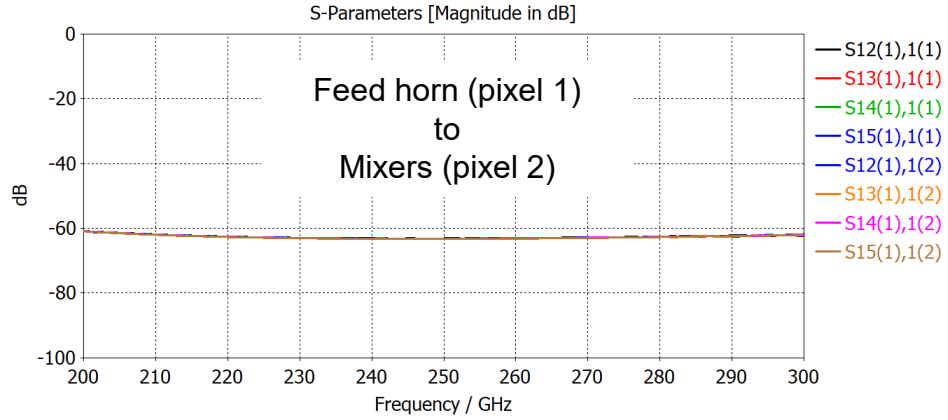


Each of these outputs would go to a 2SB mixer block module

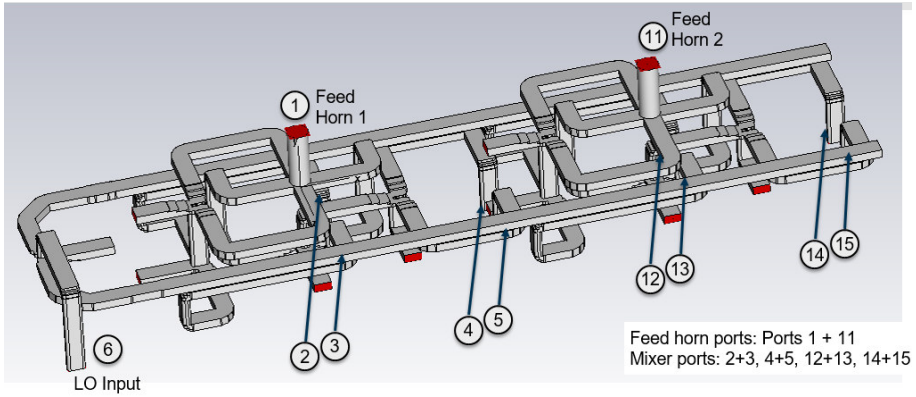
2-Pixel Array, Pixel-to-Pixel Leakage







(perfect alignment, lossless)

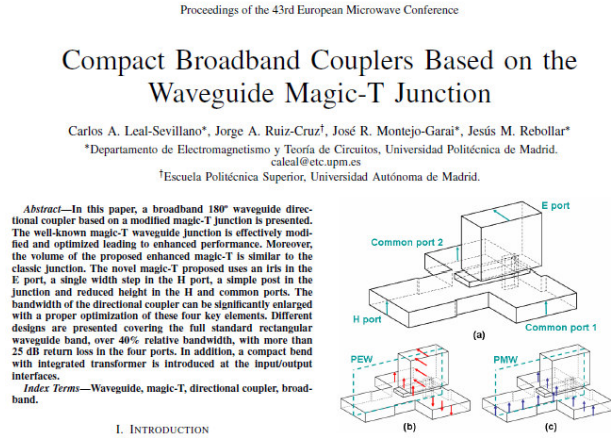


Feed horn ports: Ports 1 + 11
Mixer ports: 2+3, 4+5, 12+13, 14+15

(leakage through LO coupling path)

Hybrid-T: Key Component!

- "Magic-T" is a critical component for these platelet-type designs
- 2-layer, all metal; inspired by a paper by Carlos Leal-Sevillano
- **Collaborating with Chris Groppi (ASU) to prototype a hybrid-T to test machinability and performance**



Proceedings of the 43rd European Microwave Conference

Compact Broadband Couplers Based on the Waveguide Magic-T Junction

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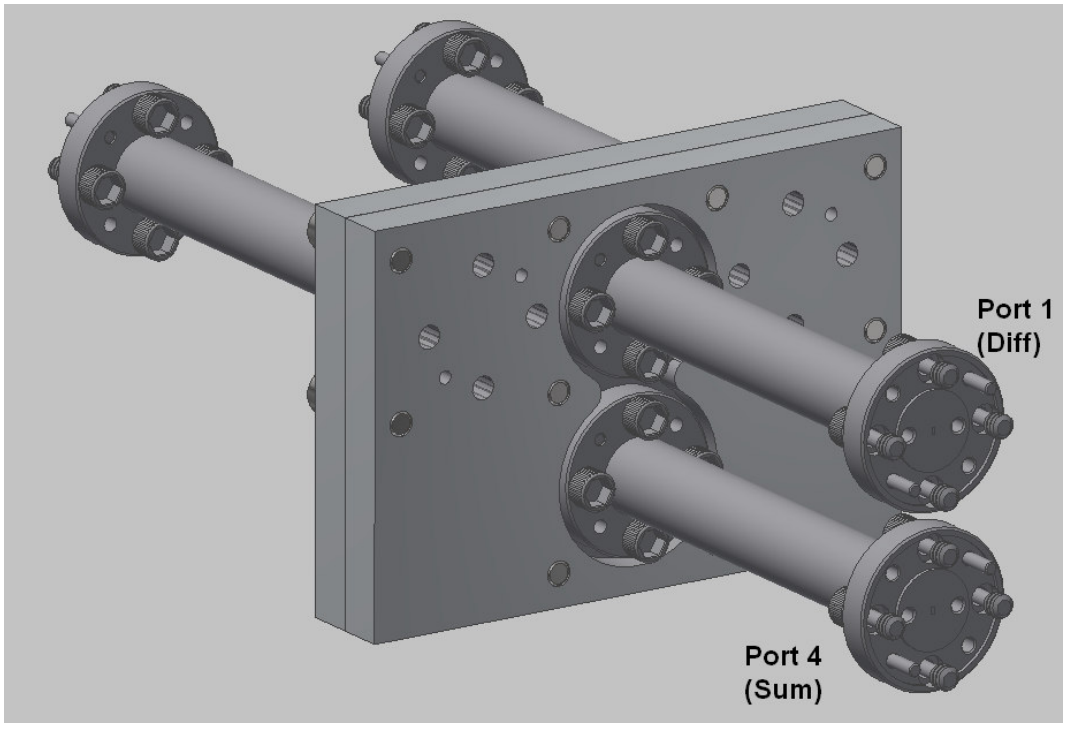
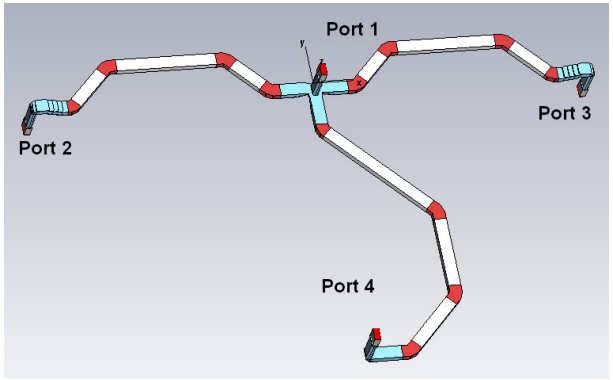
†Escuela Politécnica Superior, Universidad Autónoma de Madrid.

***Abstract*—In this paper, a broadband 180° waveguide directional coupler based on a modified magic-T junction is presented. The well-known magic-T waveguide junction is effectively modified and optimized leading to enhanced performance. Moreover, the volume of the proposed enhanced magic-T is similar to the classic junction. The novel magic-T proposed uses an iris in the E port, a single width step in the H port, a simple post in the junction and reduced height in the H and common ports. The bandwidth of the directional coupler can be significantly enlarged with a proper optimization of these four key elements. Different designs are presented covering the full standard rectangular waveguide band, over 40% relative bandwidth, with more than 25 dB return loss in the four ports. In addition, a compact bend with integrated transformer is introduced at the input/output interfaces.**

***Index Terms*—Waveguide, magic-T, directional coupler, broadband.**

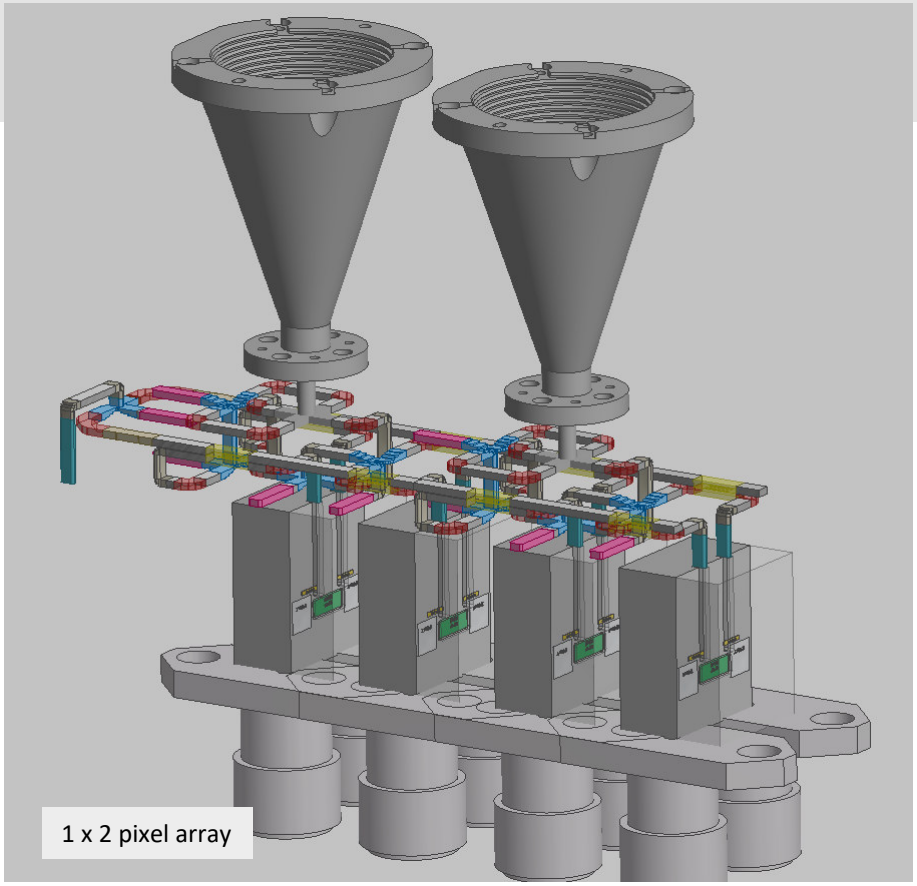
I. Introduction



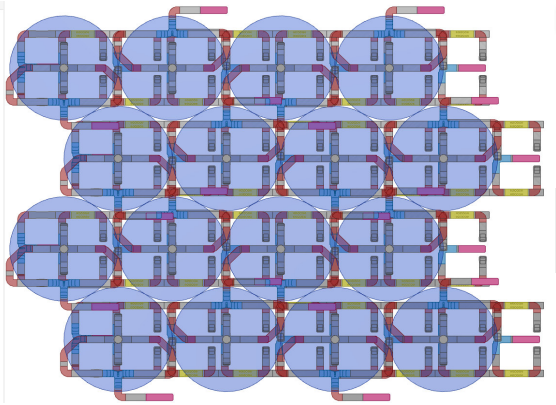


Summary

- **DL2SB “unit cell”**



- Integrate OMT, power dividers, and LO coupling
- Mixer blocks are separate + split-block
- Platelet assembly
- LO distributed along the array line



Example:
4 x 4 pixel array