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A Compact Beam-Forming Network for Switched-Beam Arrays

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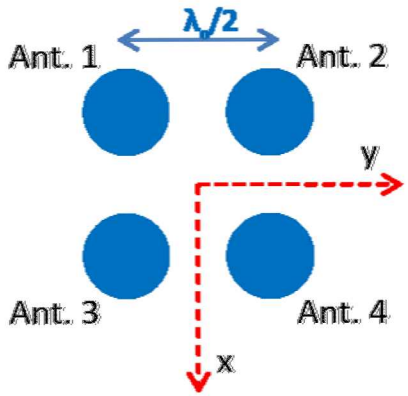
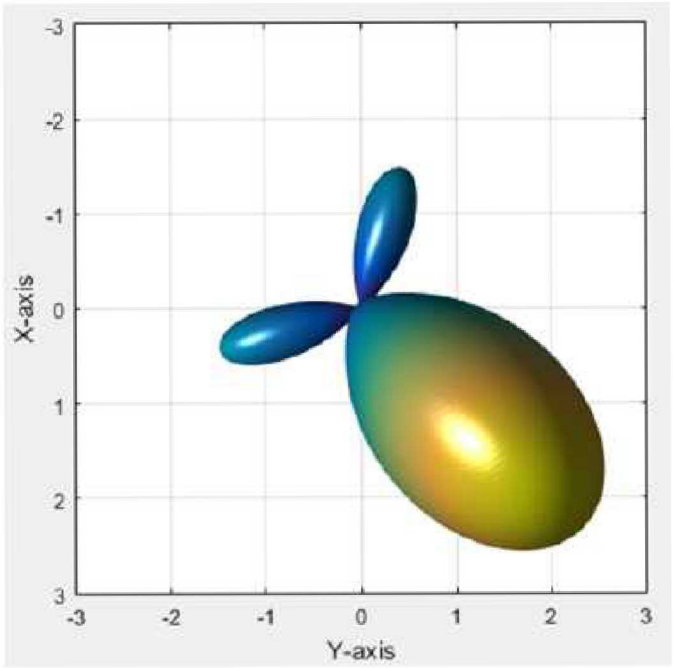
Motivation

- Applications such as satellite communications can benefit from the increased directivity of a conical antenna radiation pattern.
- Use of a conical element in a phased array can further direct energy in a desired direction.
- A 2x2 switched beam array of conical elements can provide full azimuthal coverage with improved directivity over a single element.

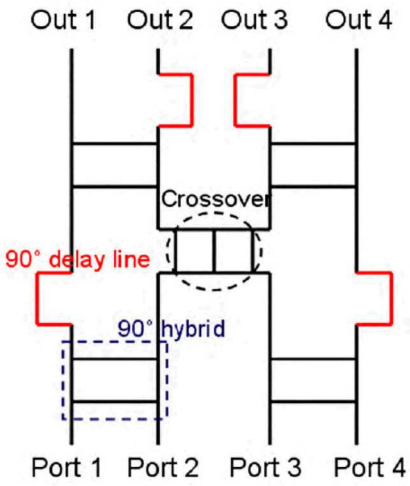


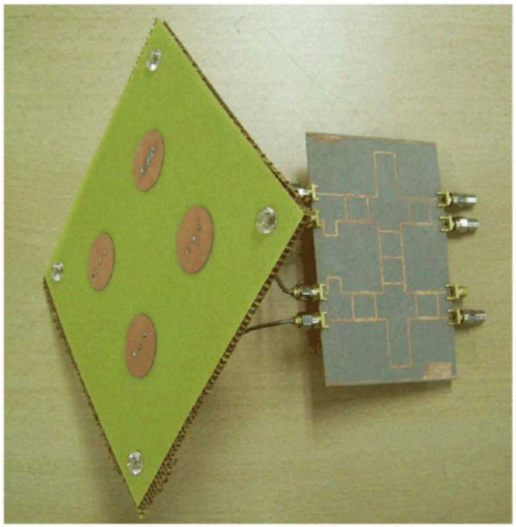
Ant. 1	Ant. 2	Ant. 3	Ant. 4
0°	90°	90°	180°
90	180	0	90
90	0	180	90
180	90	90	0



Previous Work from the Literature

- Switched beam operation is desirable for its design simplicity, durability, and low-loss characteristics (eliminates the need for electronic phase shifters).
- A Butler-matrix can provide different output phasing by switching the RF signal between various network input ports [1].
- Network designs from the literature can produce desirable phasing for switched beam operation [2].
  - The use of delay lines and cross-over networks result in narrow bandwidth and large footprint size.





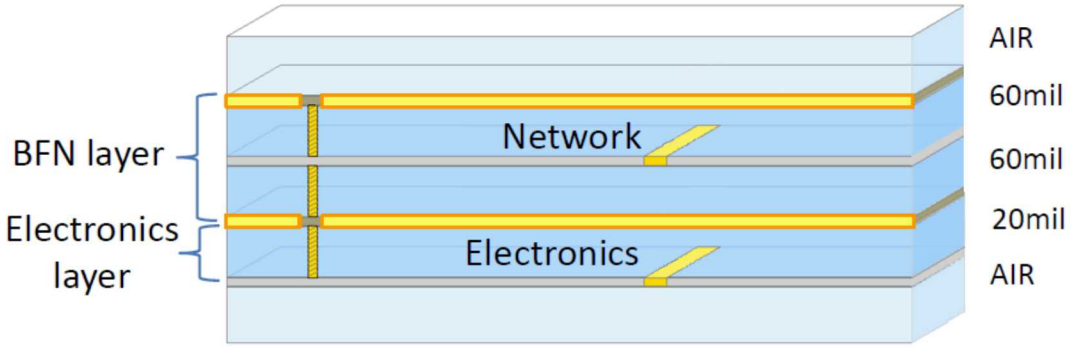
[2]

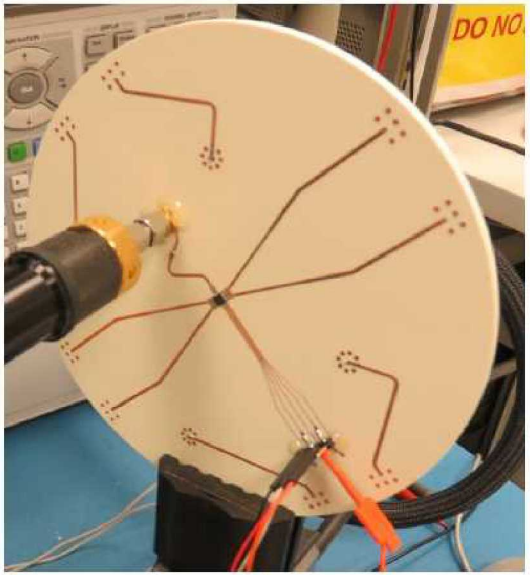
[1] J. Butler and R. Lowe, *Beam-forming matrix simplifies design of electronically scanned antennas*, Electron. Des., vol. 9, pp. 170-173, 1961.

[2] J. Kim and W. Park, *A novel feed network for a sectoral conical beam forming array antenna*, Proc. IEEE Int. Symp. Antennas and propag., pp. 1-4, Jun 2009.

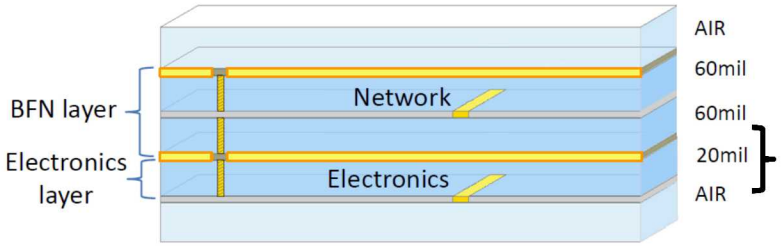
Proposed Feed Network Topology

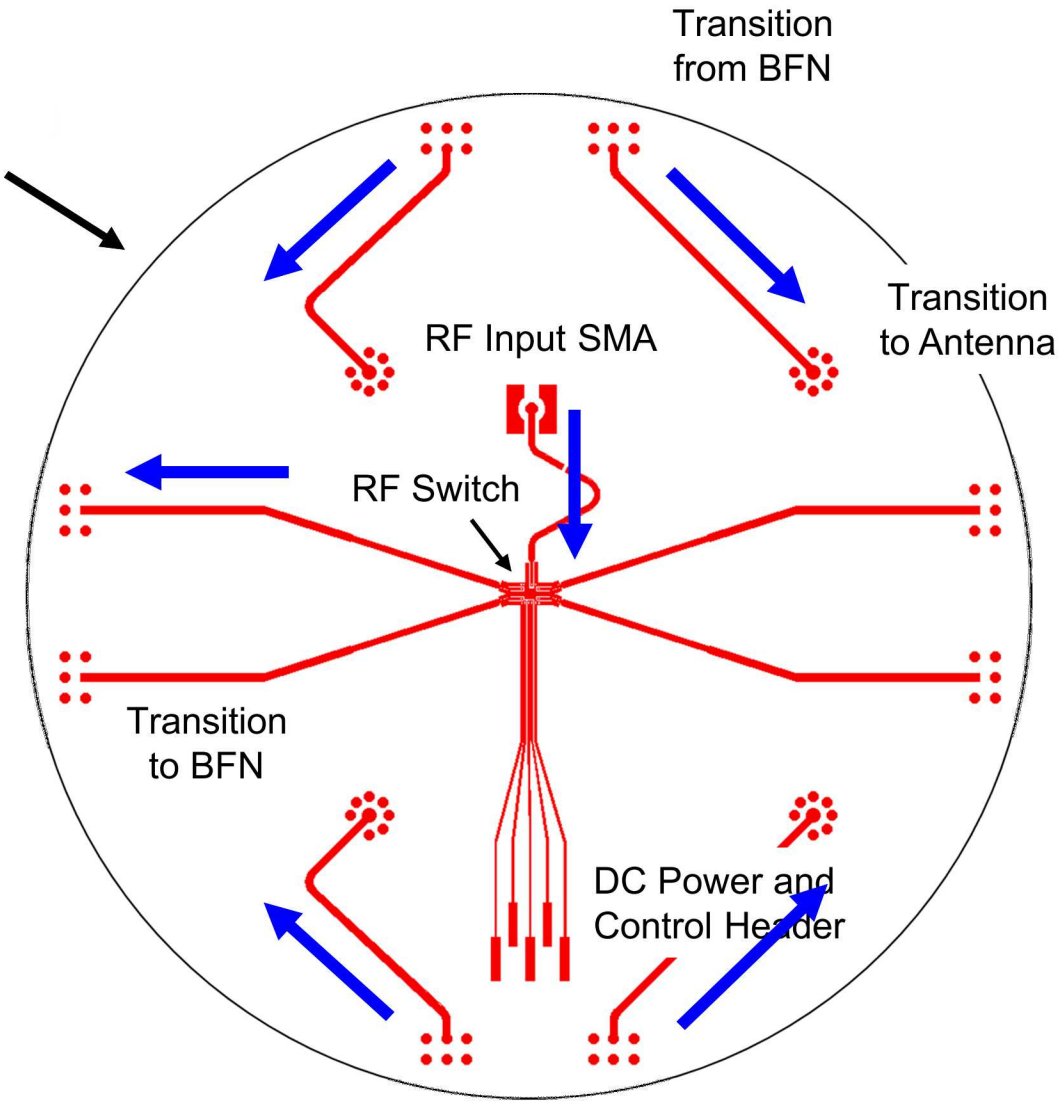
- Design consists of two functional layers (three substrates, four metallization).
  - Beam-forming network (BFN) functional layer produces the desired power division and phase shifts.
  - Electronics layer contains the RF switch, DC power, and RF distributions lines to and from the BFN.
- An antenna array layer can be bonded to the top of the stackup to form an integrated, low-profile phased array.
- Via transitions route the signal between functional layers.





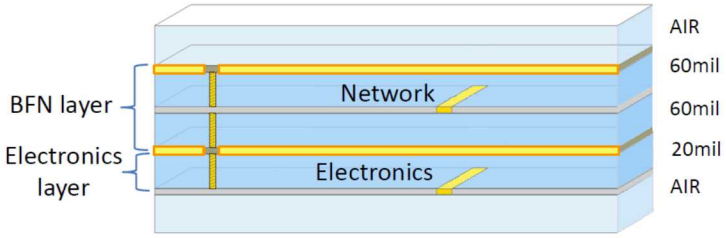
Electronics Layer Design



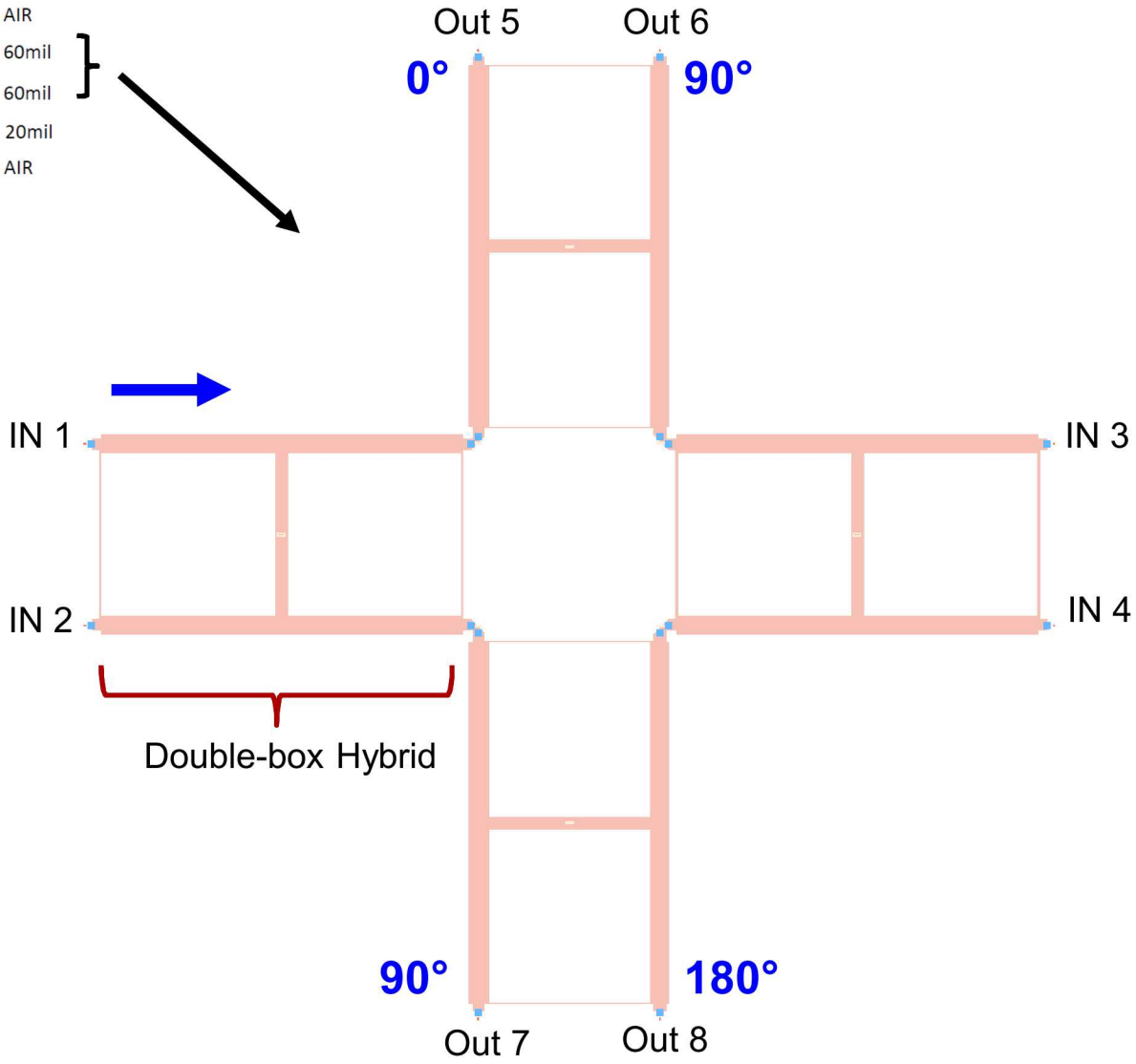


- A microstrip electronics layer forms the bottom of the stackup.
- The RF signal is switched between one of four beam-forming network inputs.
- The RF switch is a Hittite HMC241ALP3E.

Beam-Forming Network Design

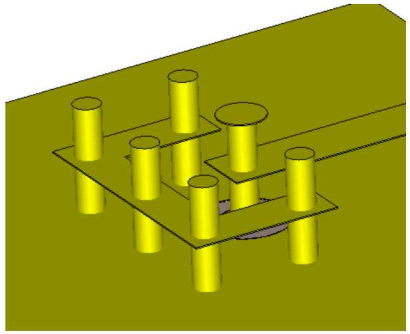


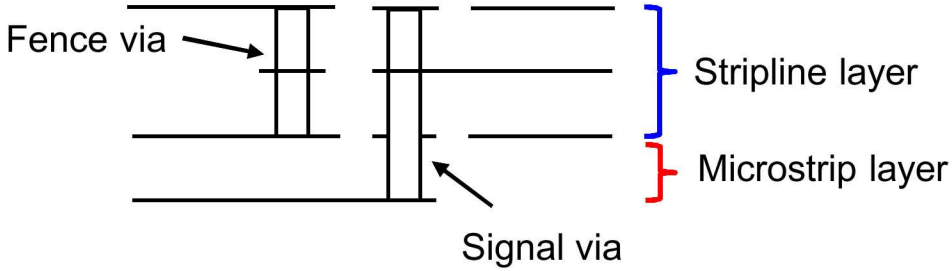
- The beam-forming network is implemented in stripline.
- The RF signal is applied at one of the four input ports through a via transition.
- The signal is divided four ways, phase shifted, and passed back to the electronics layer.



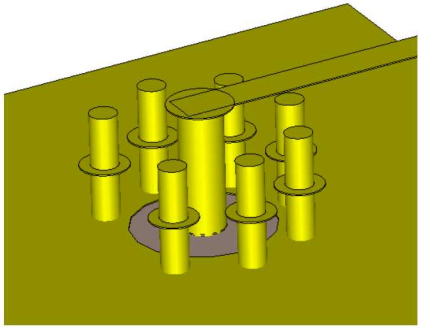
Layer Transitions

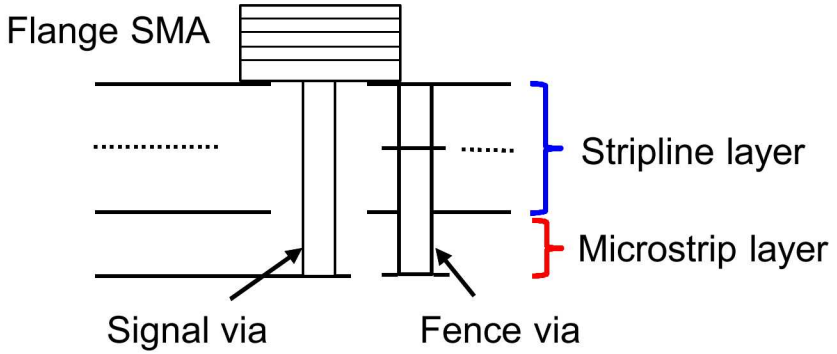
- Microstrip to stripline layer transition
  - Transfers signals between the electronics layer and the beam-forming network.





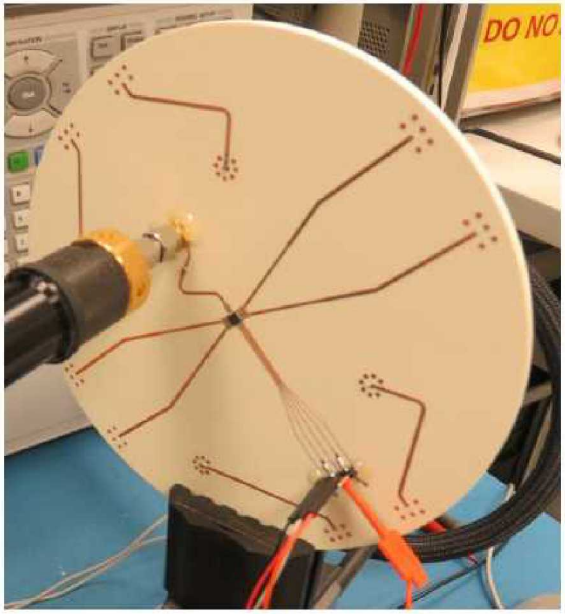
- Microstrip to SMA transition
  - Transfers signals between the electronics layer and the antennas (SMA connectors in the prototype).



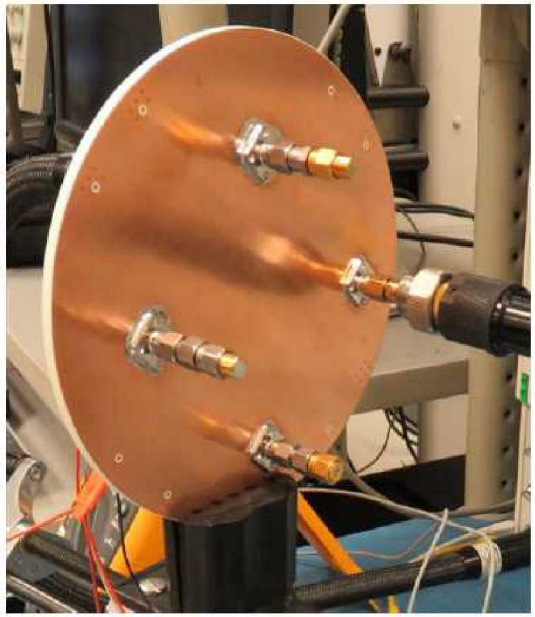


Construction

- Fabricated from 60 and 20 mil Rogers 4350® ceramic substrates.
- Connectorized for testing but can be bonded to an antenna layer for production.
- All signal vias and via fences are through vias (i.e. no blind vias) to simplify fabrication and reduce cost.

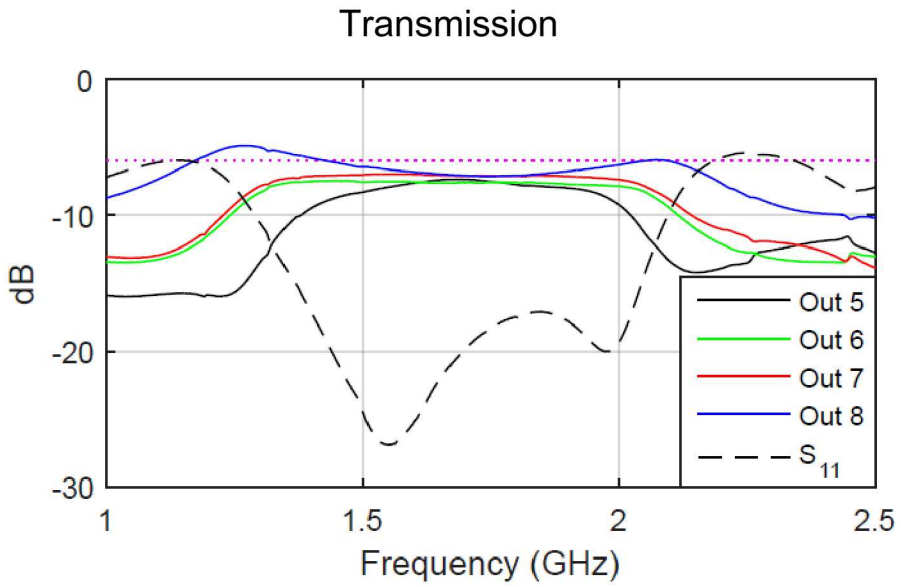


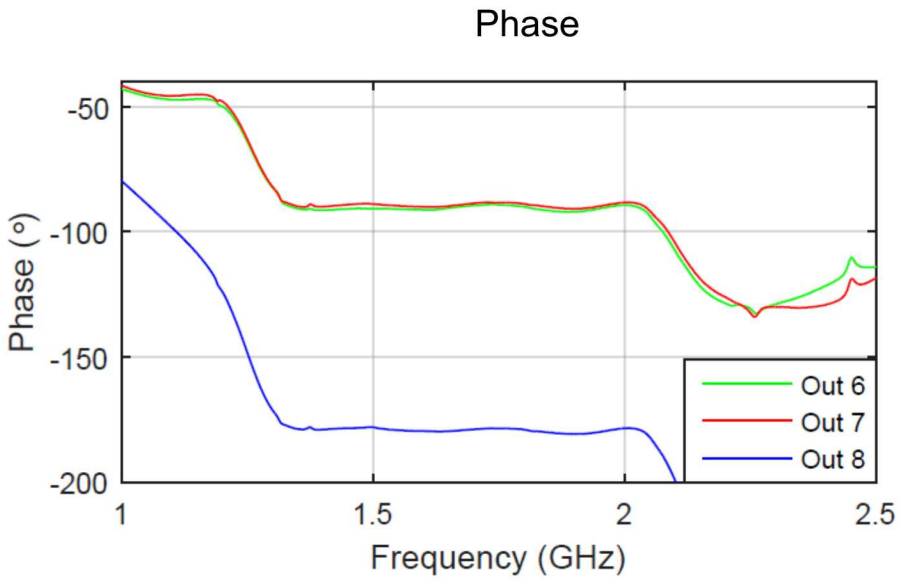
Microstrip electronics layer



Connectorized prototype

Measured Results





- The design has 22% bandwidth (1.55 - 1.93 GHz) using a 0.5 dB transmission variation criteria.
- As expected, the RF switch introduces about 1 dB of loss.
- Measured performance matches ADS Momentum® simulations closely.

Conclusions

- Feed network could be further reduced in size.
  - The use of conical array elements (~1λ diameter) limits the benefits of feed network size reduction.
- Antenna layer can be bonded to the feed network stackup to form an integrated low-profile array.
- Prototype was specifically designed to allow power amplifiers to be added immediately before the antenna elements.

Acknowledgement

- Bernd Strassner, Jacques Loui, and Wade Freeman of Sandia National Laboratories for helpful technical discussions related to this work.