MODELING OF A 192-WAY WAVEGUIDE POWER DIVIDER

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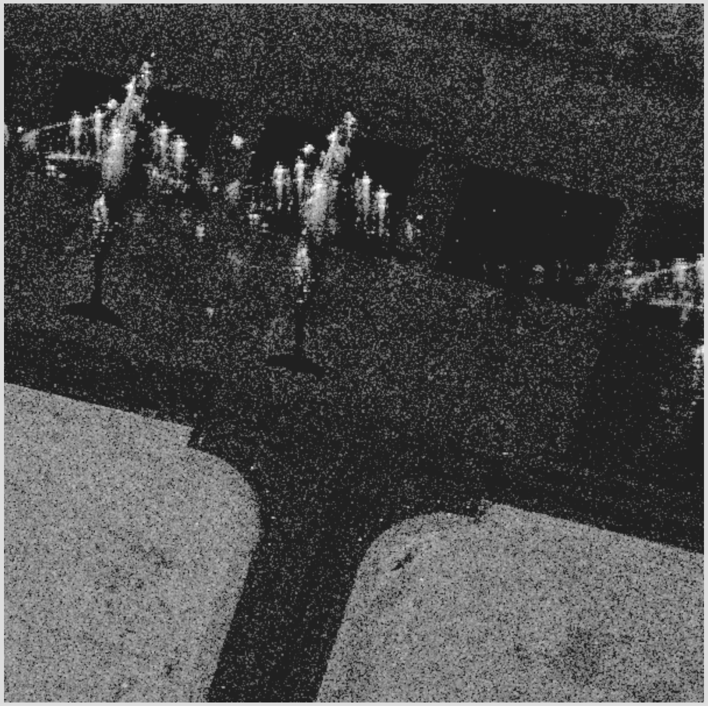
Ansoft HF Users' Workshop, Los Angeles, CA, January, 2002

Abstract

A 192-way, waveguide power divider is designed, modeled and validated through prototype dividers. The structure is part of the power distribution network that controls the Taylor amplitude weighting for a Synthetic Aperture Radar antenna. Ansoft High Frequency Structure Simulator with Optimetrics was used to determine the optimal design for each transition. The design process relies on heavy use of the macro language to maximize model reuse and minimize design cycle. The described procedure is suitable to any large power distribution network with non-uniform amplitude distribution.

Background

Lockheed Martin M&DS – Reconnaissance Systems division in Goodyear, AZ develops and produces airborne Synthetic Aperture Radar (SAR) Systems. The waveguide power distribution network described in this presentation is part of an antenna for a podded SAR system.



Examples of SAR Images

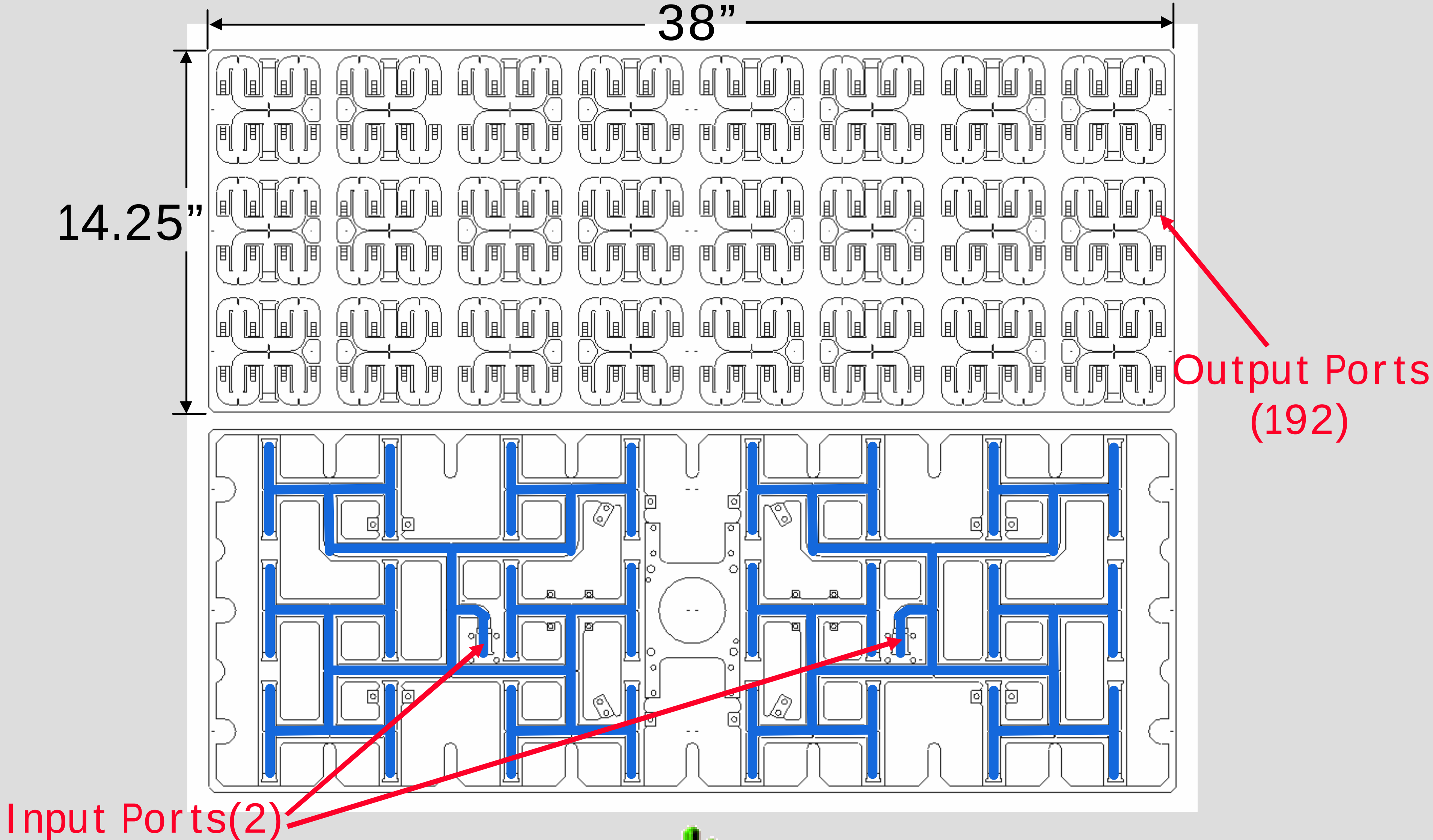
SAR System in a Pod

SAR POD

Antenna Design

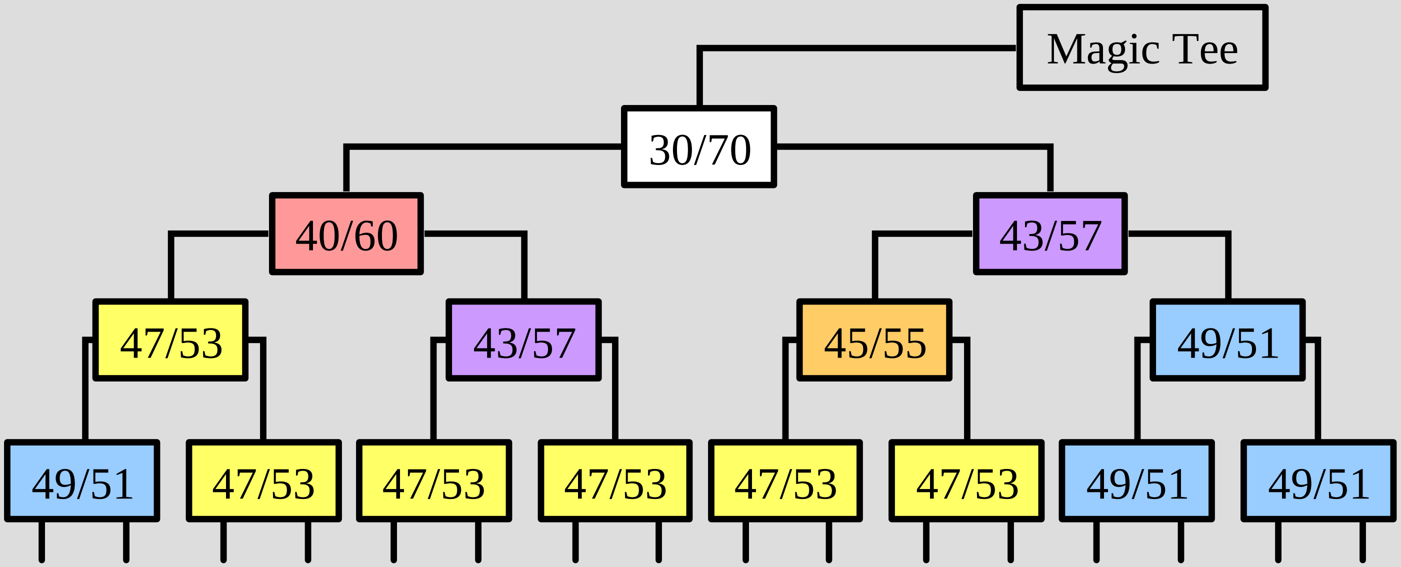
- The SAR Antenna discussed in this presentation has stacked patch radiators that are fed with both a waveguide power distribution network and a microstrip distribution network.
- There are a total of 1536 radiating elements.
- The antenna weighting requirements are uniform amplitude in elevation and 20 dB, n_bar=3, Taylor weighting in azimuth.
- The waveguide power distribution network is the means by which the non-uniform amplitude weighting is achieved. This requires a 1-to-192 network and many unequal power splits.
- The system is Ku-Band and both WR-62 and WR-51 waveguide are used.
- The antenna aperture is 38” x 14.25”.

Waveguide Power Divider



Amplitude Weighting

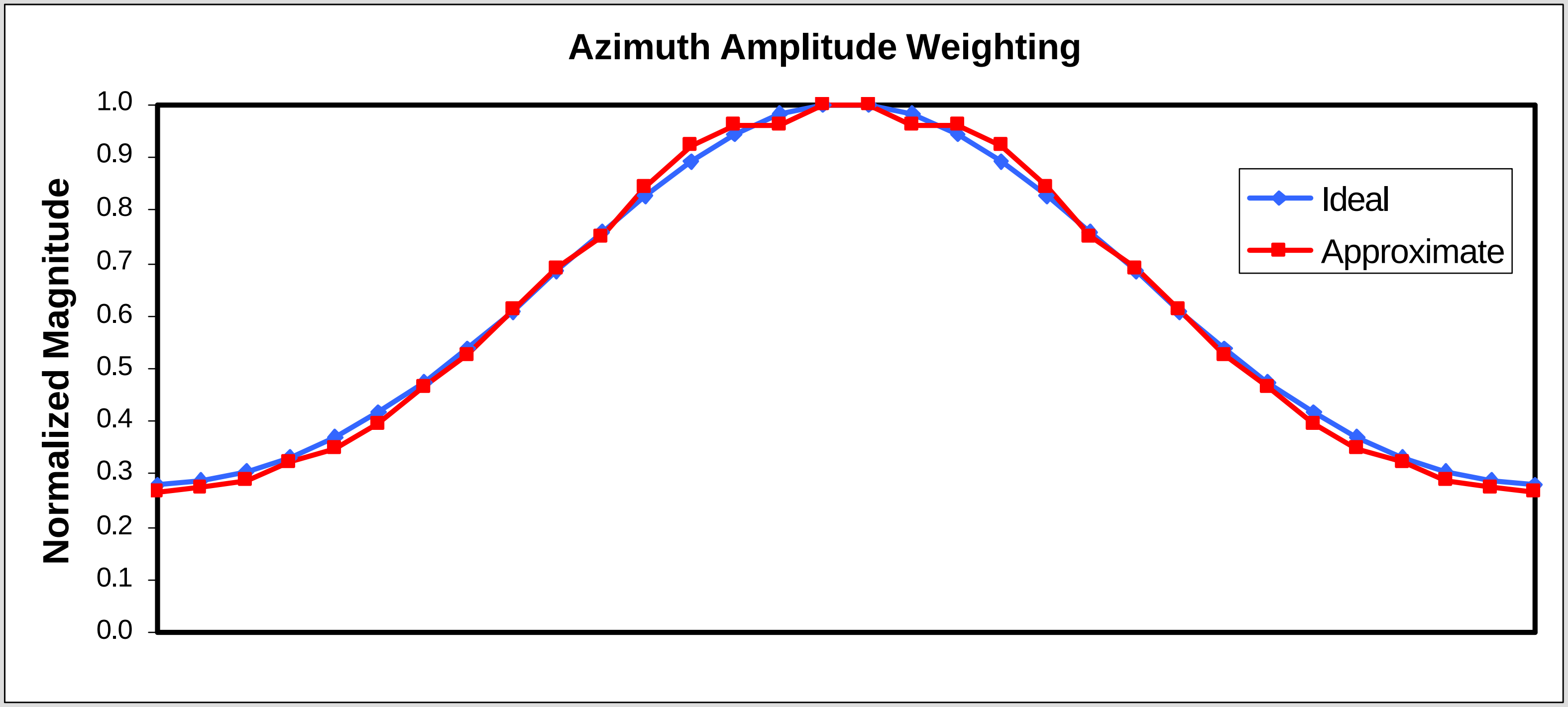
- 16 waveguide power dividers are needed to achieve the 1-to-32 azimuth distribution. The number of unequal power divider types was reduced to 6 for the azimuth power division to simplify the design. Six was determined to be sufficient (see the following page). The power split ratio and location were chosen such that the resulting amplitude weighting was close to the ideal weighting.
- A 2-to-1 power split was used for the elevation power distribution



Azimuth Power Division

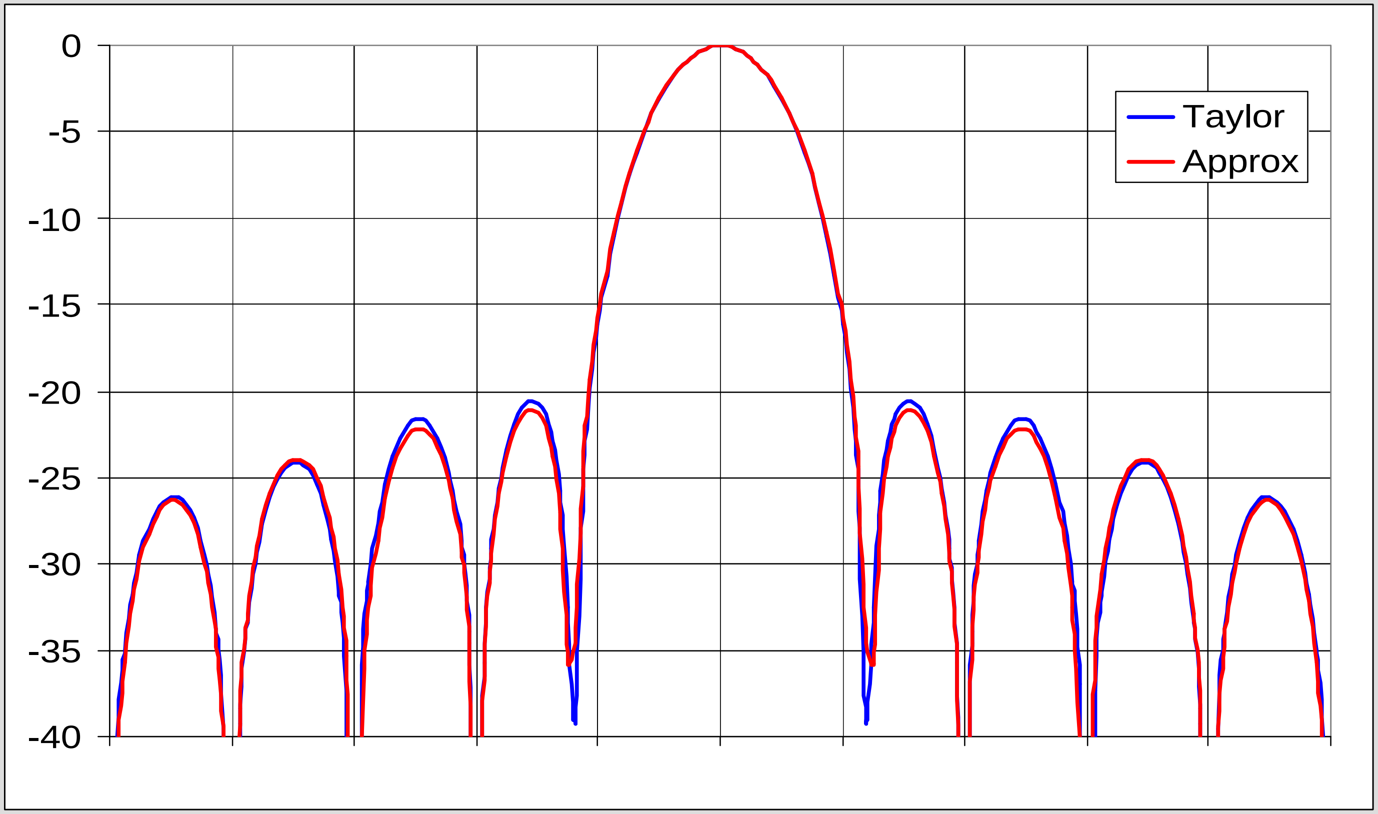
Amplitude Weighting

- The following plot shows the ideal azimuth Taylor weighting and the weighting generated using a reduced number of power divider types.



Far Field Patterns

- Amplitude approximation due to reduced number of power dividers types has little impact on the far field antenna patterns.
- The first two sidelobes are reduced by ~0.5 dB.

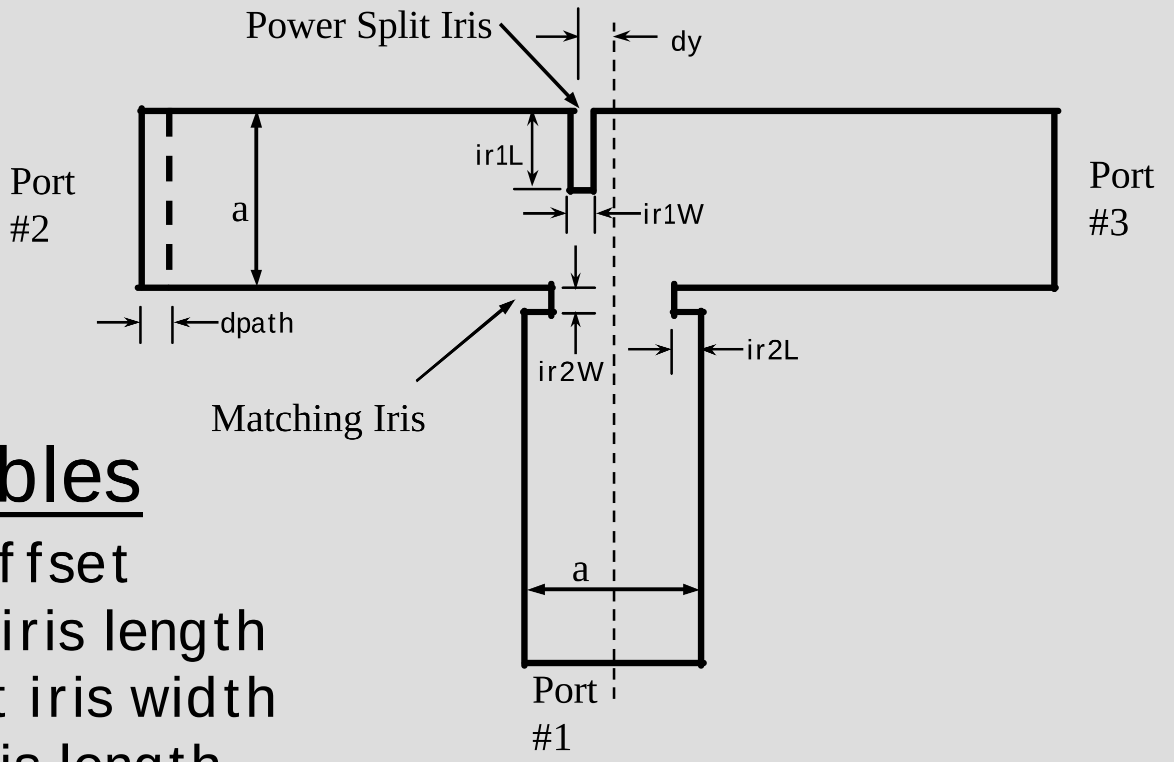


Waveguide Power Divider

- Determined logical points to break the problem into pieces that can be modeled using Optimetrics.
  - Single power dividers
  - Waveguide bends: H-plane and E-plane
  - WR-62 to WR-51 transformer
- An H-plane waveguide power divider was chosen for its geometrical advantages.
- The double-iris H-plane T-junction configuration[1] was chosen because it is relatively easy to manufacture and integrate.
- Prototypes were made and tested to validate the design concept and the HFSS modeling.

[1] J. Joubert & S.R. Rengarajan, "Design of Unequal H-plane Waveguide Power Dividers for Array Applications", Proceedings of the IEEE Antennas and Propagation Society International Symposium 1996, Vol. 3, pp 1636-1639, Baltimore, USA, 21-26 July 1996.

Double-Iris H-Plane T-Junction

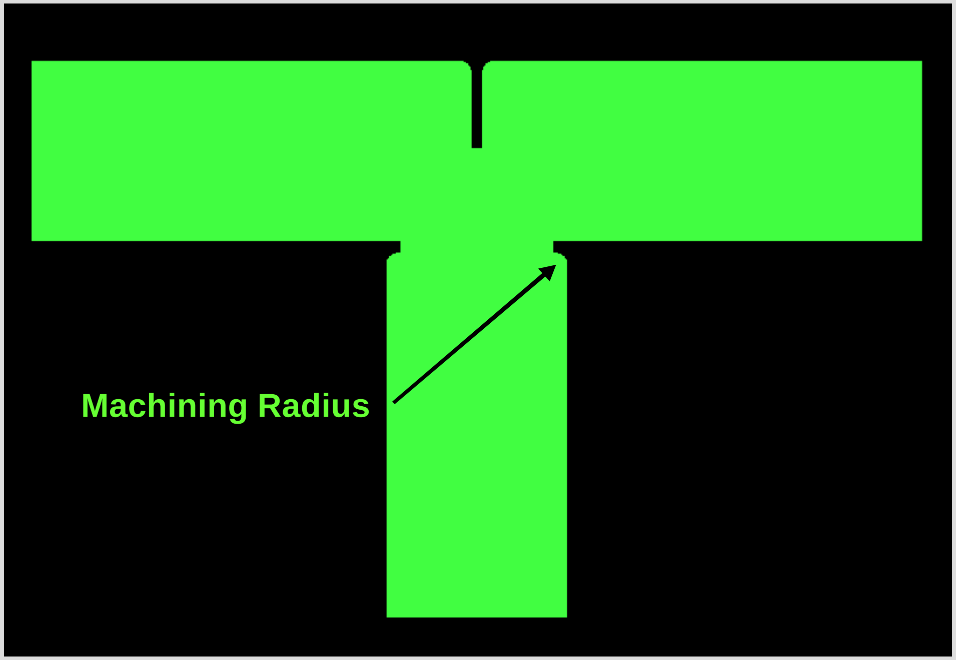


Design Variables

dy = power split offset
ir1L = power split iris length
ir1W = power split iris width
ir2L = matching iris length
ir2W = matching iris width
dpath = delta path length

HFSS Models

- The T-Junction model was used to determine the iris geometry, offset, and phase differential.
- This was completed for each power divider type.
- A macro was built for this model and Optimetrics was used to iterate to the optimum geometry.



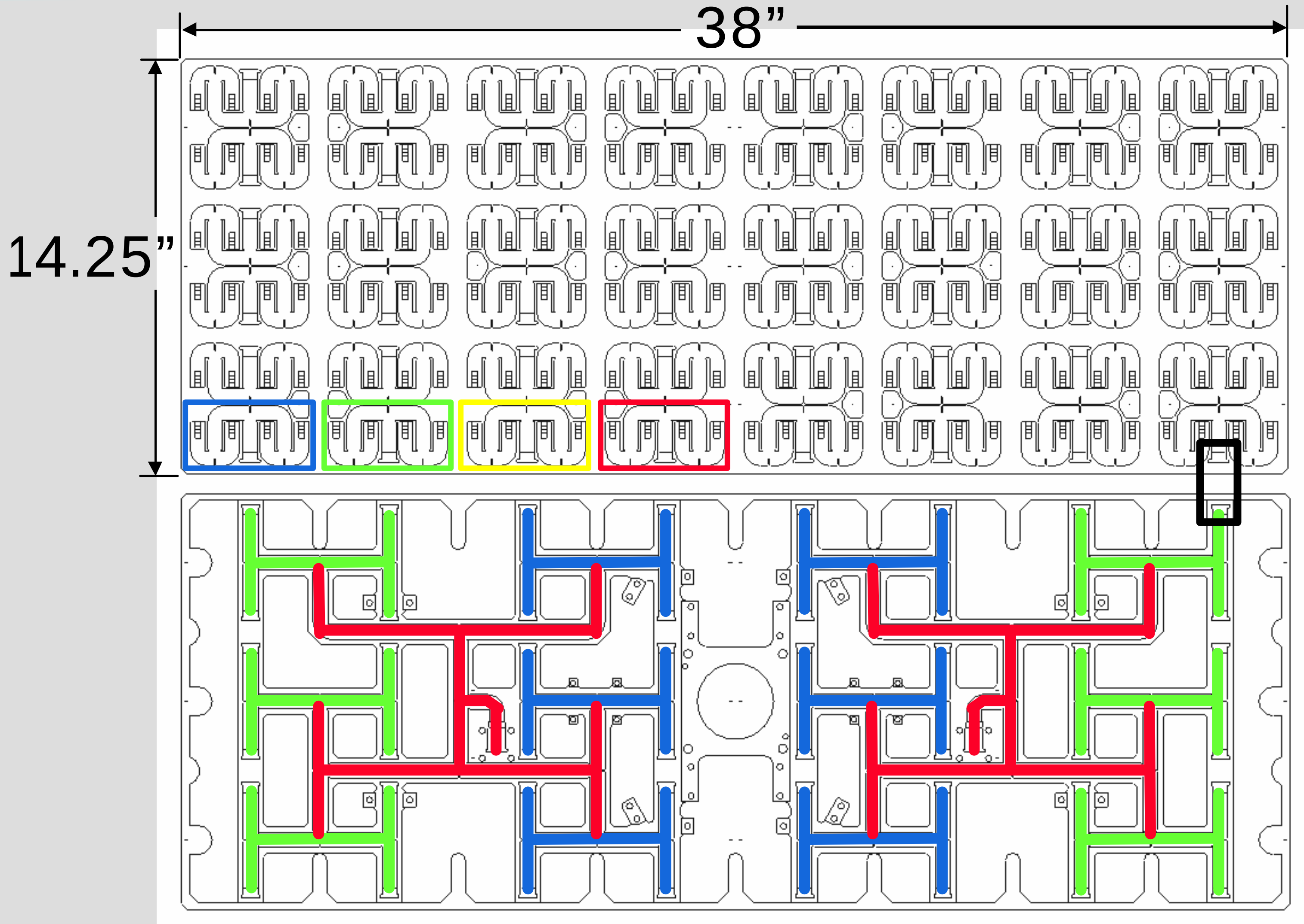
- The inside corners that are left by the milling process have a measurable impact on the electrical performance and were included in the model.
- Prototypes of this type of power divider were manufactured and the RF performance matched the simulated data very well.

HFSS Models

- The next step is to take the individual 3-port power dividers and create the next higher level model.
- Using the baseline model, more complex models were built to capture the effects of nearby transitions.
- Power division and phase were adjusted at this level.

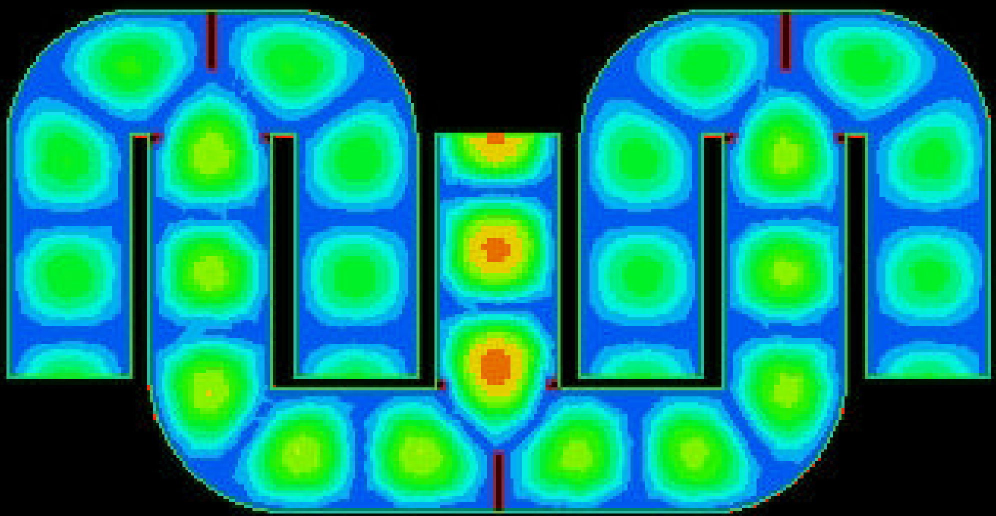
- The Filter Cost Function is used to achieve a flat amplitude response across the entire bandwidth (use the Equal To curve) and minimize the return loss (use the Below curve). These filter cost functions were combined into a single cost function to optimize to the required performance.

Waveguide Power Divider



HFSS Models / Results

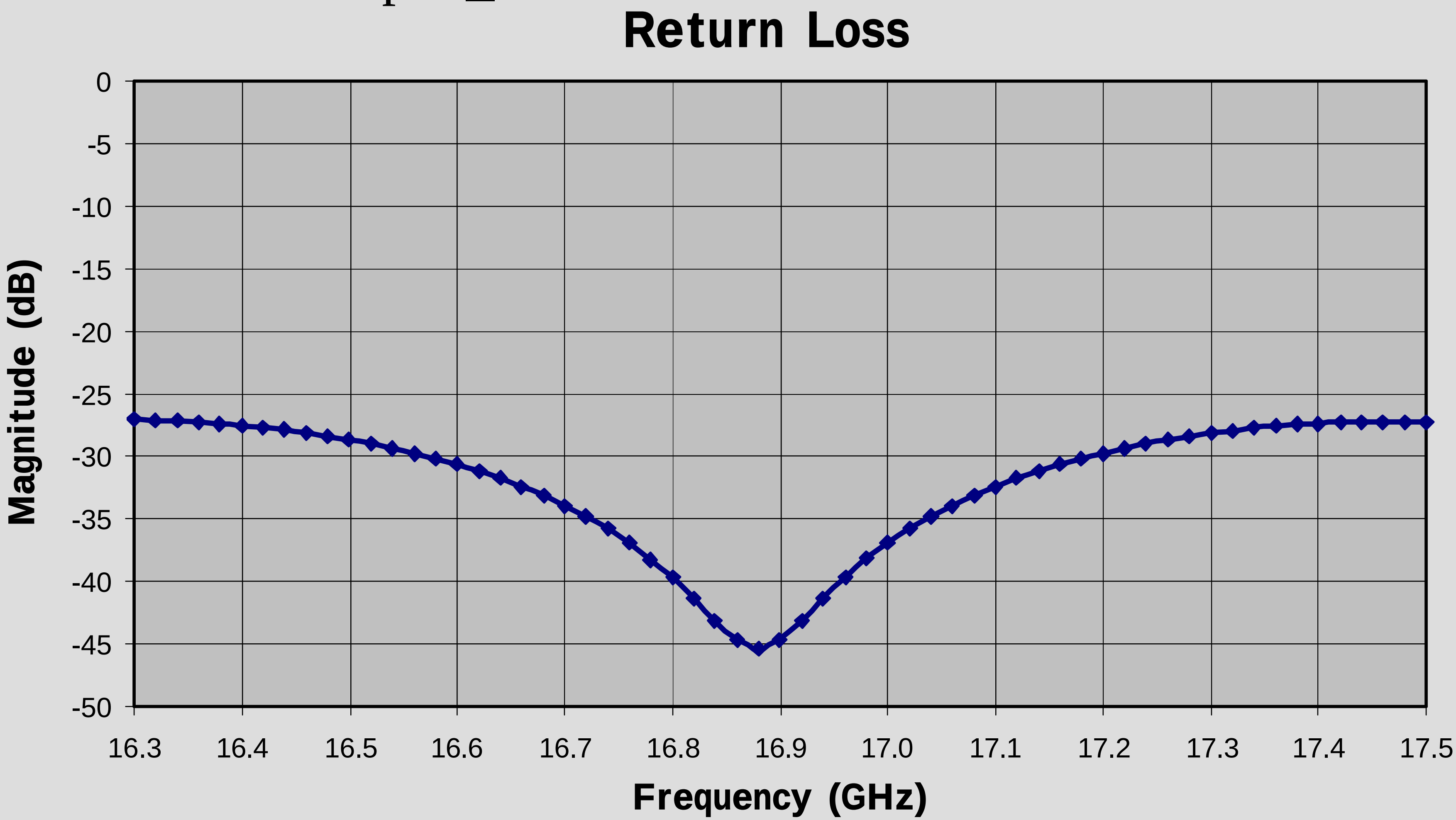
HFSS Model "pd4_4"



E-Field Plot

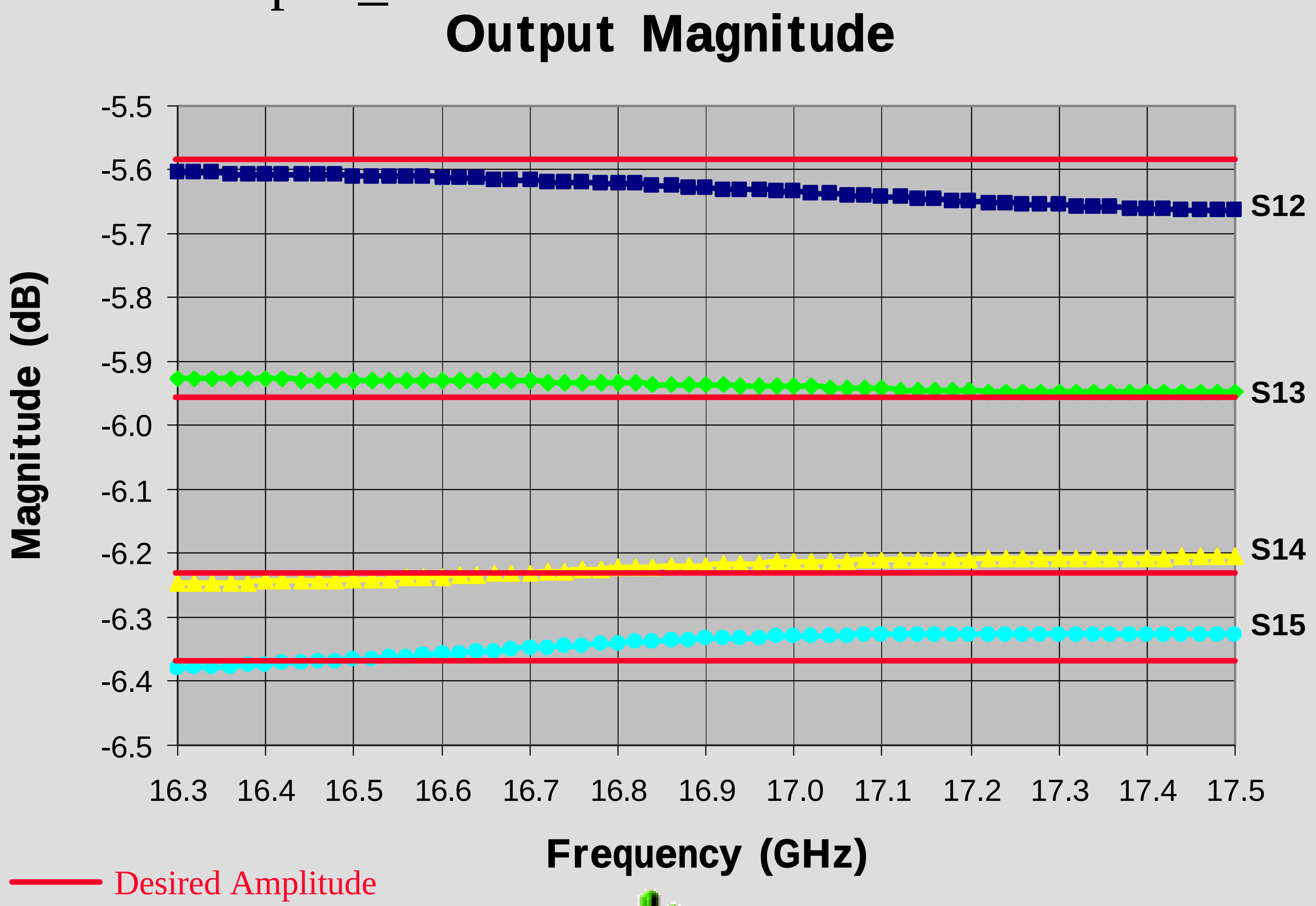
Return Loss

HFSS Model “pd4_4”



Power Split

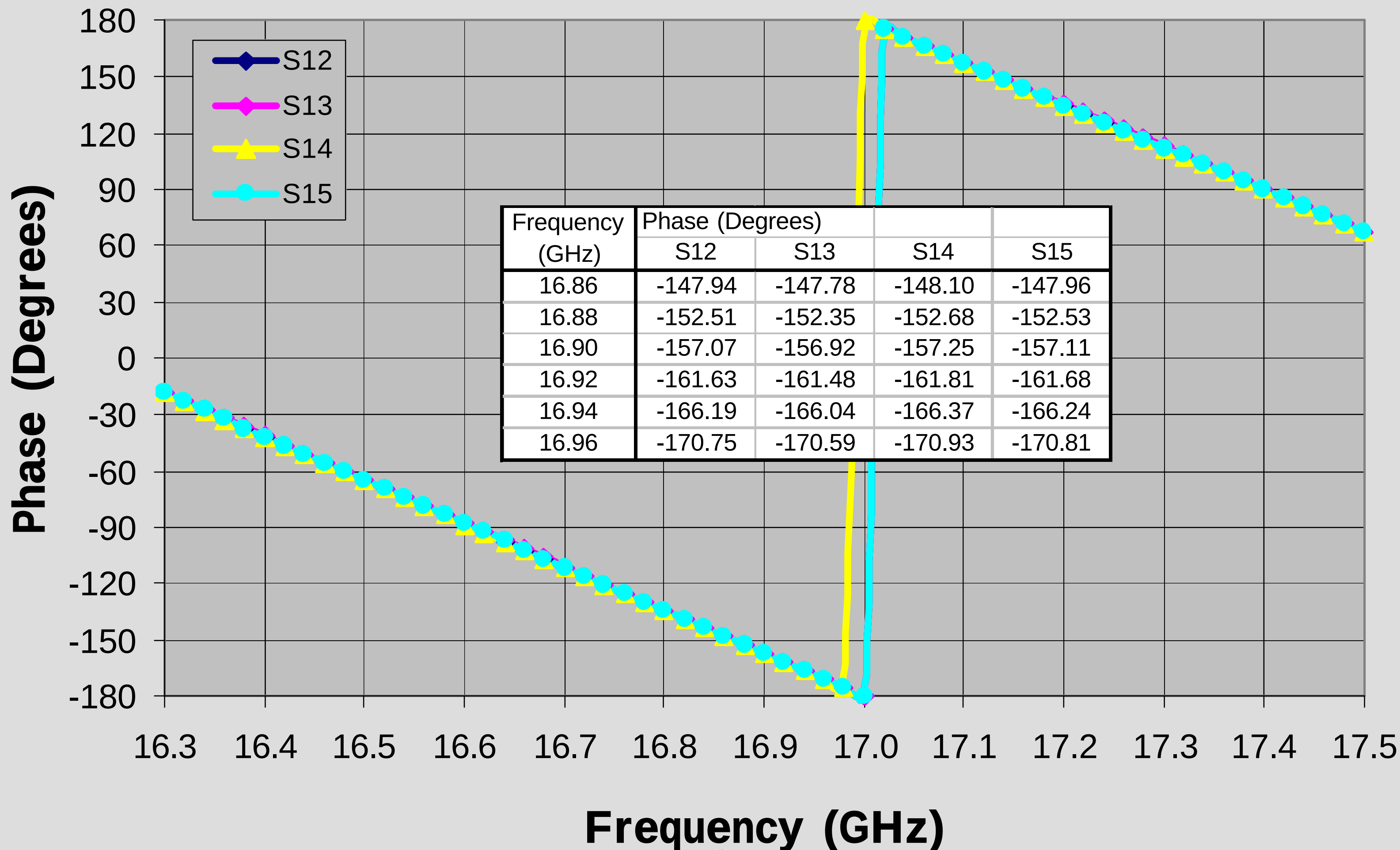
HFSS Model “pd4_4”



Phase Matching

HFSS Model “pd4_4”

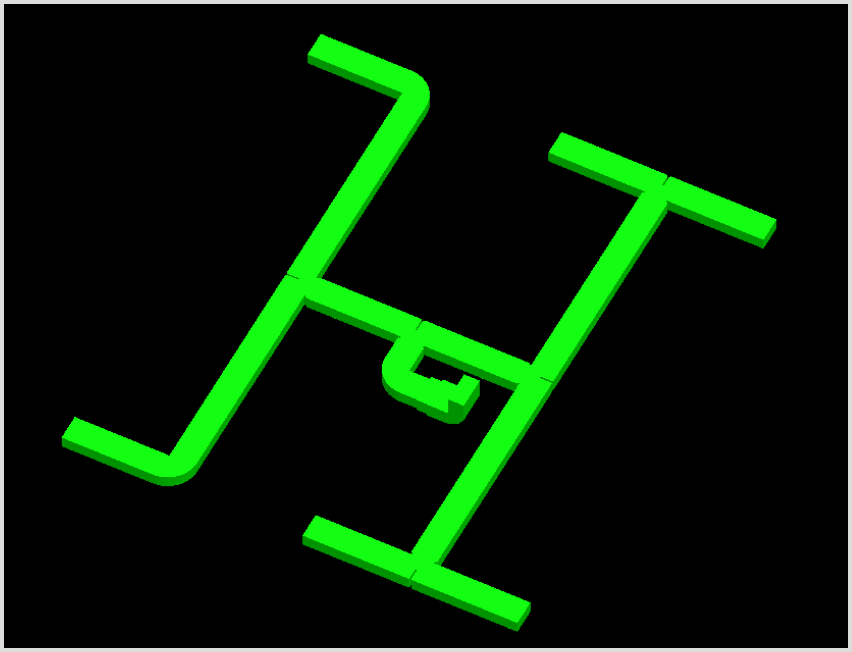
Phase Match

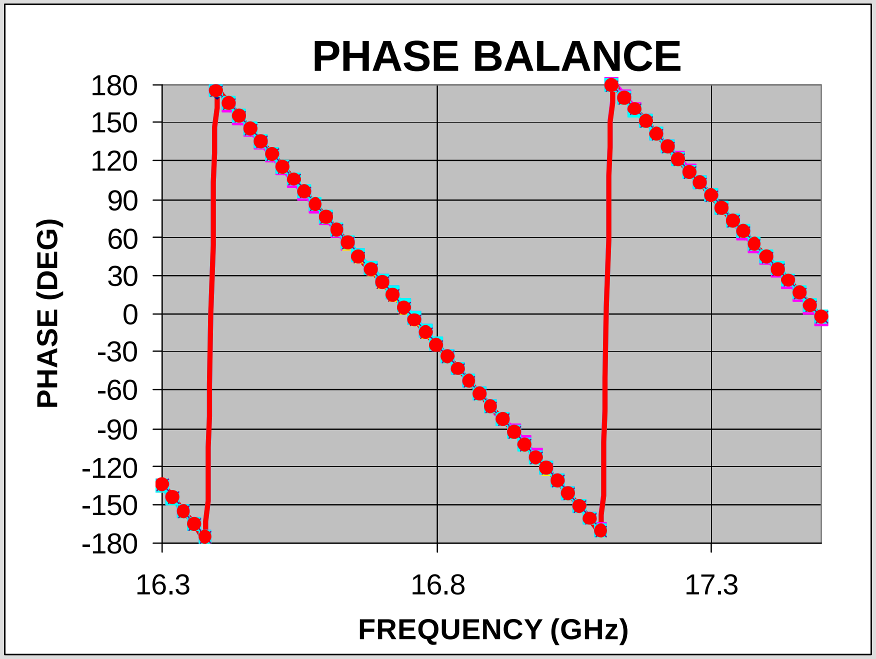


Frequency (GHz)	Phase (Degrees) S12	S13	S14	S15
16.86	-147.94	-147.78	-148.10	-147.96
16.88	-152.51	-152.35	-152.68	-152.53
16.90	-157.07	-156.92	-157.25	-157.11
16.92	-161.63	-161.48	-161.81	-161.68
16.94	-166.19	-166.04	-166.37	-166.24
16.96	-170.75	-170.59	-170.93	-170.81

Top Layer Power Dividers

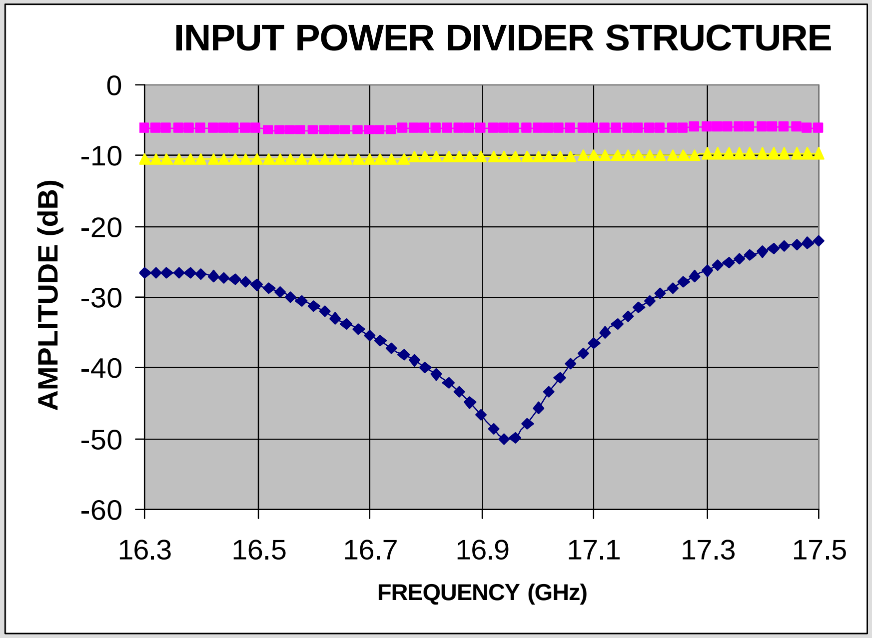
- The amplitude and phase optimization of the 4-way power dividers determined the location of the 180 degrees E-plane bends that transition to the top layer of waveguide power dividers.
- Two 5-port models and the 7-port model shown here complete the waveguide hogout power divider modeling.

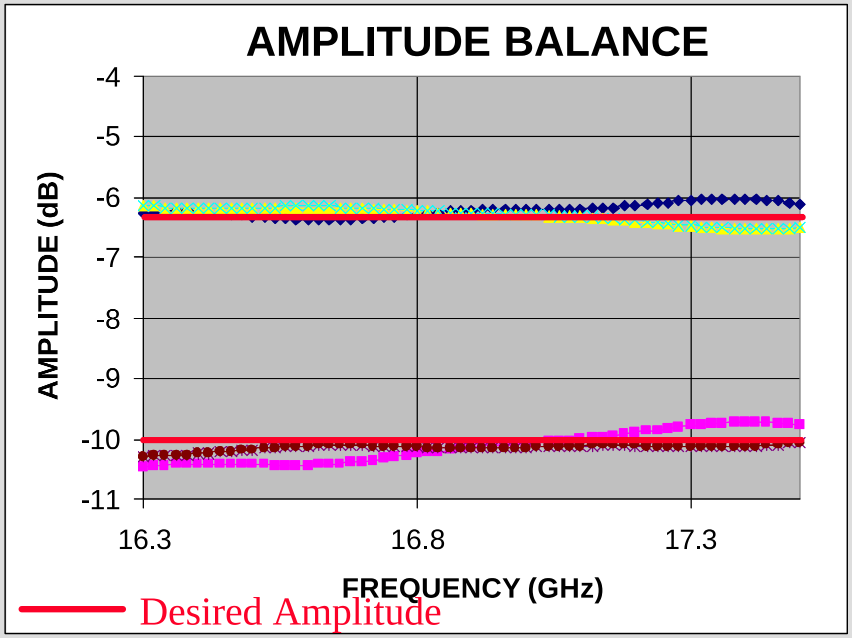




Top Layer Power Dividers

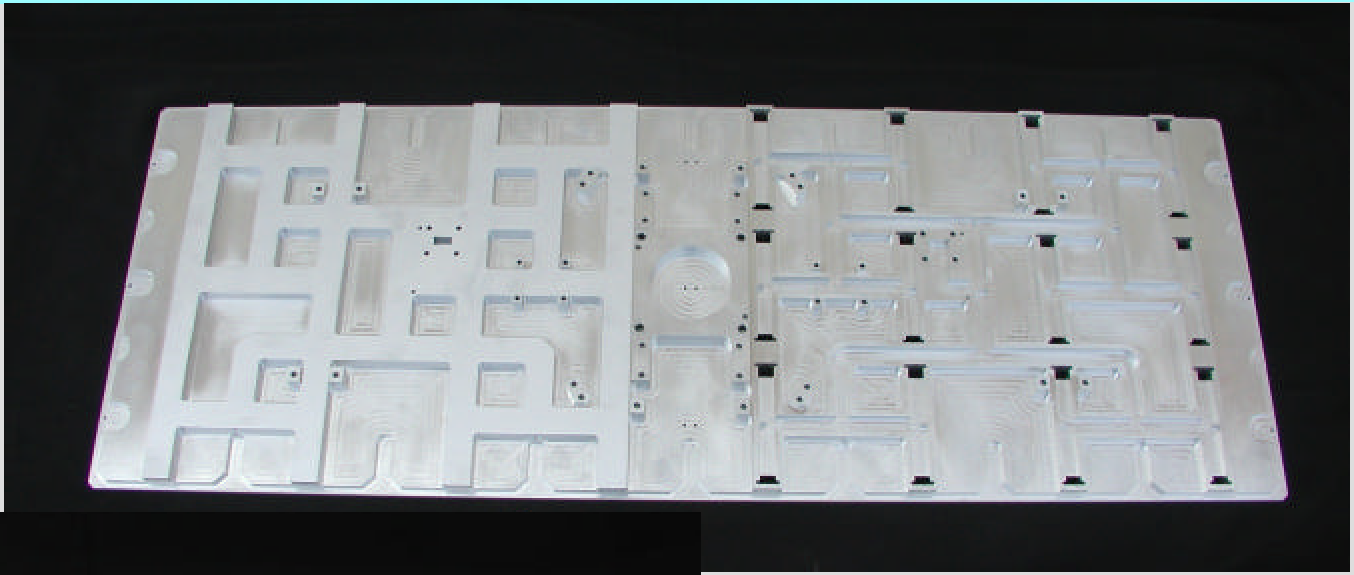
- Results are from the 7-port model pictured on the previous slide.
- The desired amplitudes are –10 dB and –6.32 dB.
- This model includes the two greatest unequal power splits.
- Also included is the transformer from WR-62 to WR-51.
- This was the largest waveguide power divider modeled.

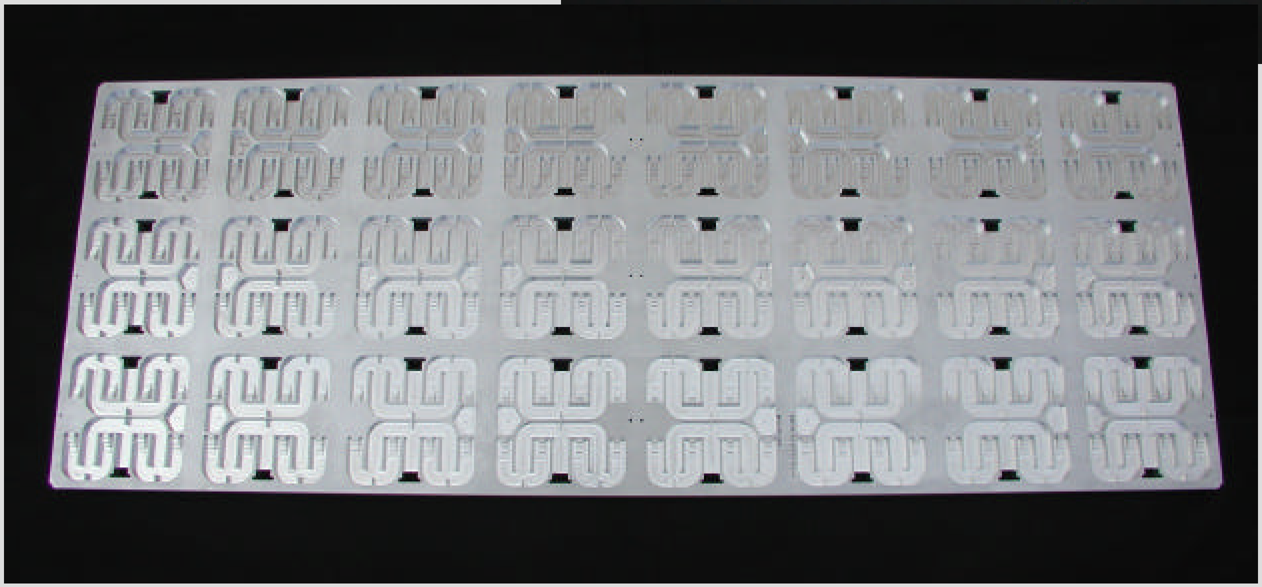




Photos of the Waveguide Power Divider

Layer 1 →





← Layer 2

Summary

- Large power divider networks with non-uniform amplitude distributions require many different power splits.
- Depending on the performance requirements, some simplifications may be made by simply reducing the number of power split types.
- Design a generic power divider design and identify the parameters that can be varied to meet all the requirements.
- Generating a baseline model using the macro language with variable parameters minimizes model development time by maximizing model reuse. This has positive impacts on cost, schedule, and repeatability
- Using Optimetrics allows the user to reach the best design in the least amount of time.