Large Aperture, Scanning, L-Band SAR (Membrane-based Phased Array)

Sponsored by the
Instrument Incubator Program (IIP)

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In participation with:

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Phil Smith	**TR Testing**
Mark Zawadzki	**Antenna Design**
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Maurio Grando	**Antenna Measurement**

Outline

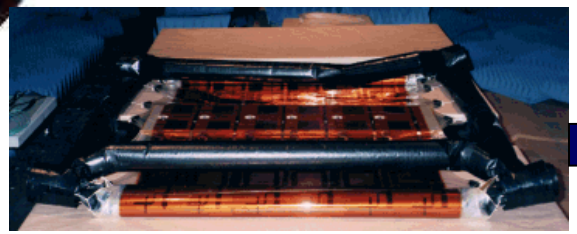
- Objective and Science Goals
- Task overview
- Technical Development and Measured Results
  - Membrane Antenna Development
  - Electronics
  - Measurement Setup and Results
- Conclusions and Future Work

Objective and Science Goals

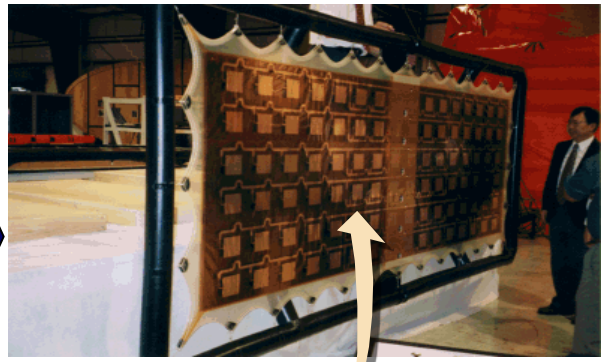
Develop lightweight active membrane phased array technologies for Synthetic Aperture Radar (SAR). This will allow placing larger SAR systems (>400m^2) at high orbits (MEO/GEO), increasing coverage.

Rigid arrays	**Membrane antennas**
heavy 10-20kg/m^2, expensive	low mass 2kg/m^2, smaller stow volume, lower cost

Roll-up SAR Antenna (stowed)



Roll-up SAR Antenna (partially deployed)



Roll-up SAR Antenna (deployed)

Past work, JPL

Applications for L-band Synthetic Aperture Radar (SAR)

- Surface deformation and strain measurement for monitoring seismic and volcanic activity
- Natural and manmade hazard monitoring, assessment and disaster response
- Soil moisture measurement, biomass, land cover change, ocean circulation and ice motion

Electronics Integration with Radiating Aperture

Task Overview

We are developing active membrane array technologies for future large (>400m^2) phased array radars.

16x16 Element Sparse Active Array

-Based on our previous ACT work (membrane-compatible Transmit/Receive (TR) modules and a 2x4 element active membrane array) we developed a 16x16 element (3mx3m antenna, 2.3mx2.3m antenna active area,) active array. We integrated this active antenna with radar backend electronics and conducted measurements of the antenna.

- Addressed manufacturability & signal distribution issues of a large membrane antenna.
- Developed membrane compatible TR modules

Active Membrane Antenna Architecture

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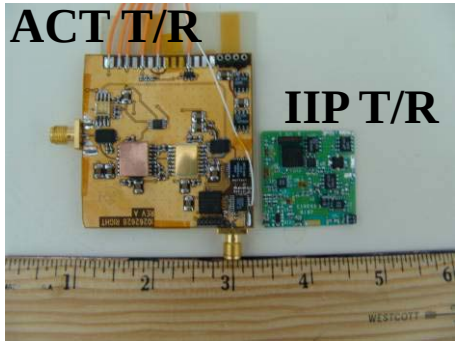
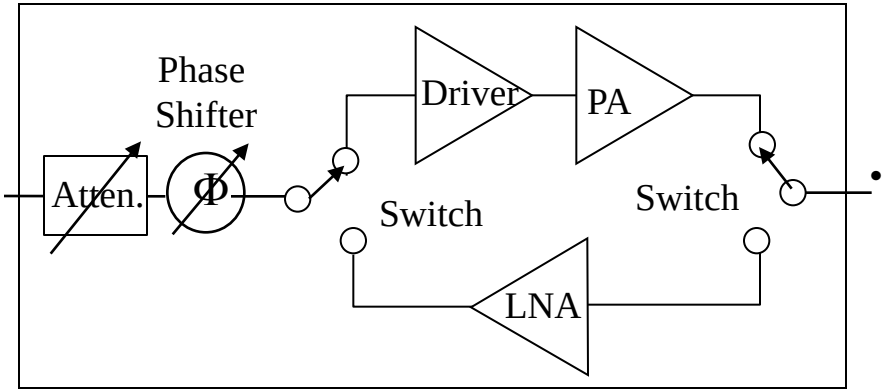
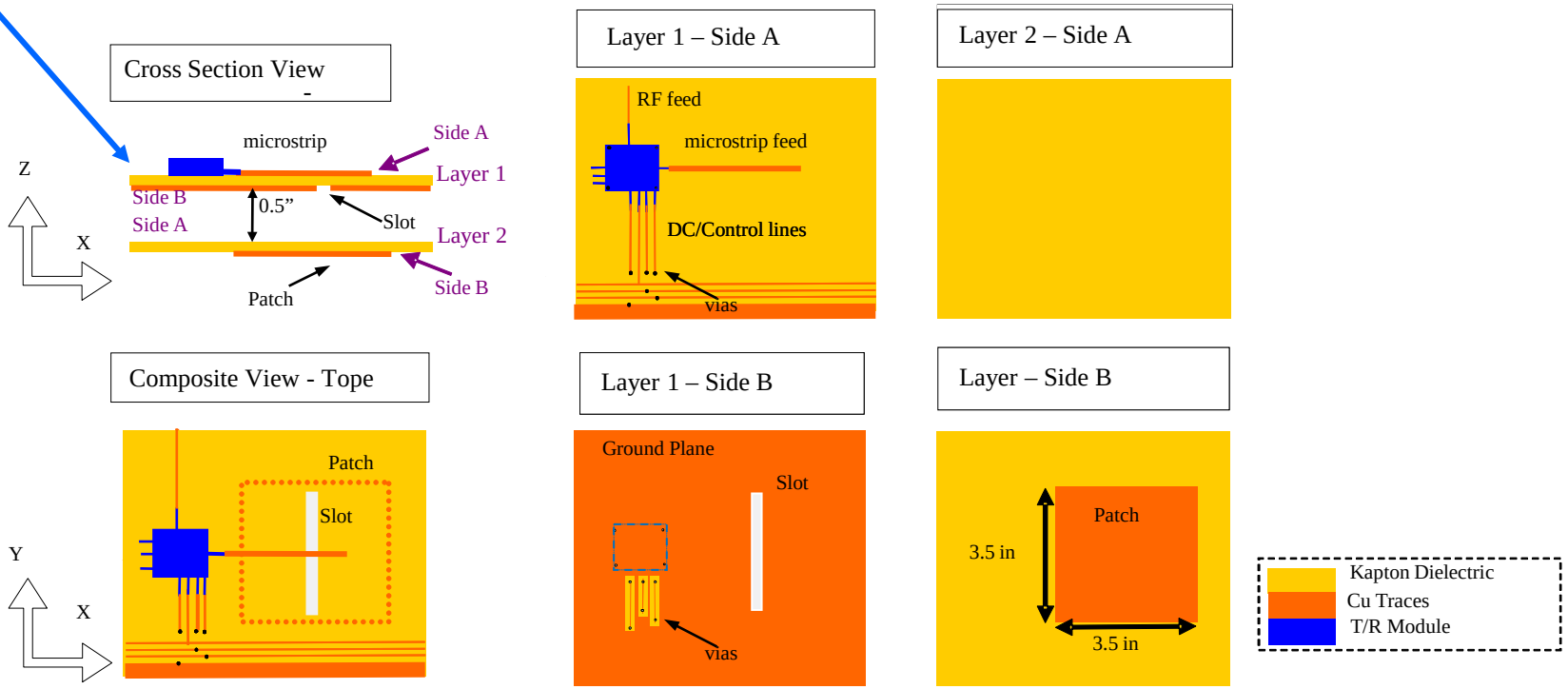


T/R Module, packaged parts



- **Miniaturized (hybrid design):** The new TR module will be smaller than the previous ACT TR module
- **Increased capability/output power:** The new TR module will have more capabilities (voltage regulators, storage capacitors, higher power)

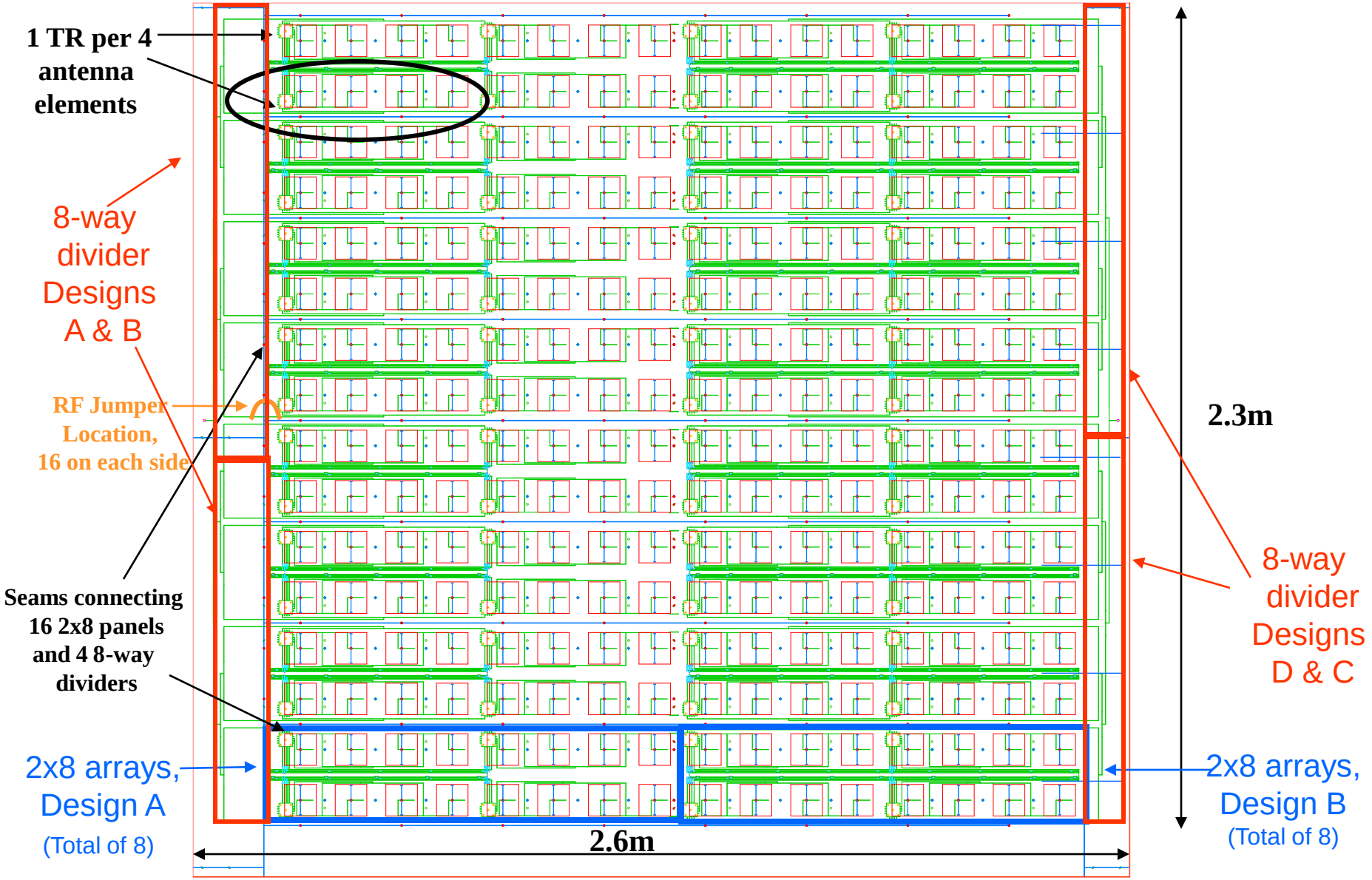


Antenna Construction and Assembly

16x16 Sparse Active Array (64 TRs)

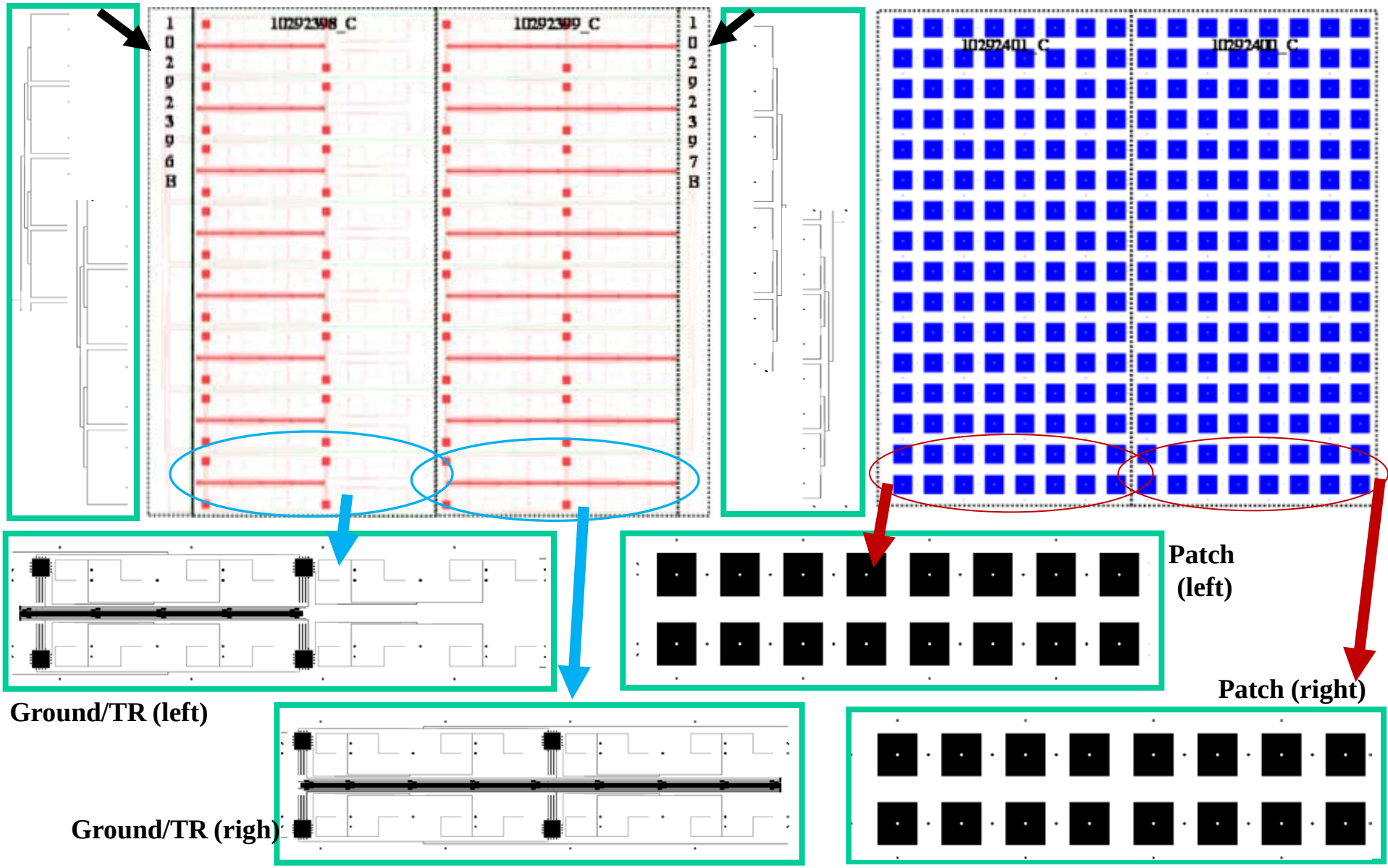
California Institute of Technology

Composite drawing of the 2 layer active membrane antenna

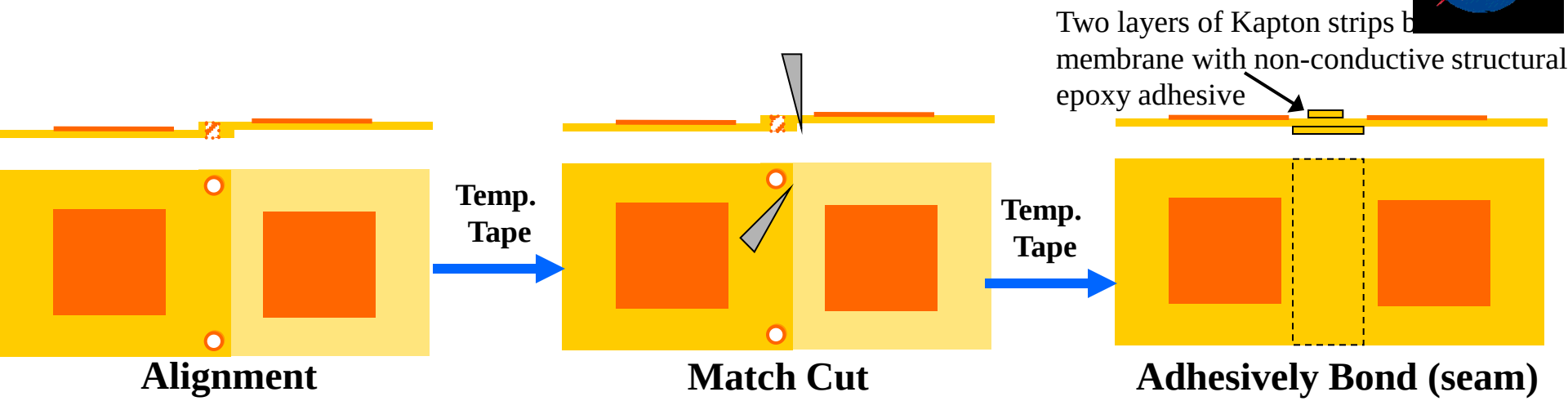


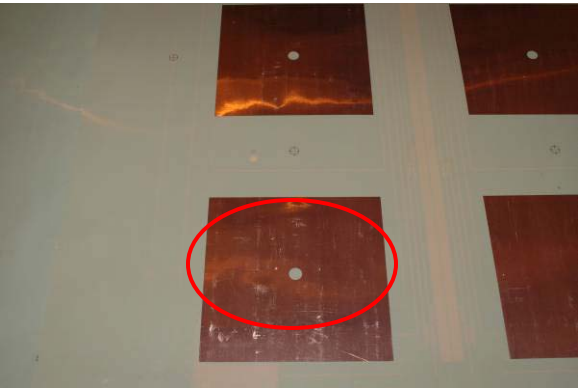
16x16 Array & Board Layouts

California Institute of Technology



Patch Panel Seaming





Alignment Marks

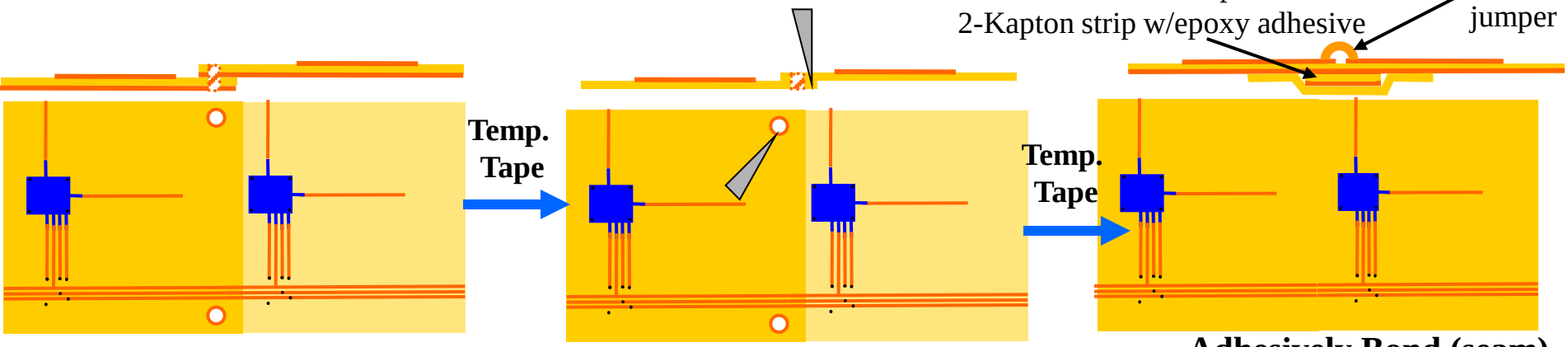
Purchased 98 inch Neolt Rolling Blade Electric Trimmer

-Features self-sharpening, hardened steel rolling blades matched with stainless steel flat blades.
-Rolling blades are mounted on a ball bearing transport system that is in turn mounted on a chrome plated guide rail.
-Result is a trimming system that gives a smooth, clean cut on a wide variety of materials.
-Florescent tube lighting illuminates the full length of the cutting area and clamp strip holds material firmly.
-Positive belt drives power trimmer heads through the cutting zone at a constant speed.

Feed Panel Seaming

Two layers of tape:
1-Double sided Cu tape
2-Kapton strip w/epoxy adhesive

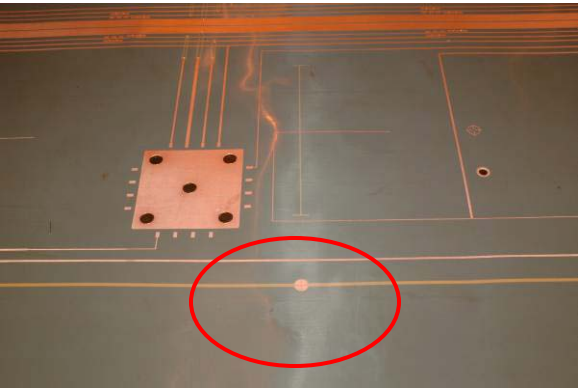
Soldered Cu jumper



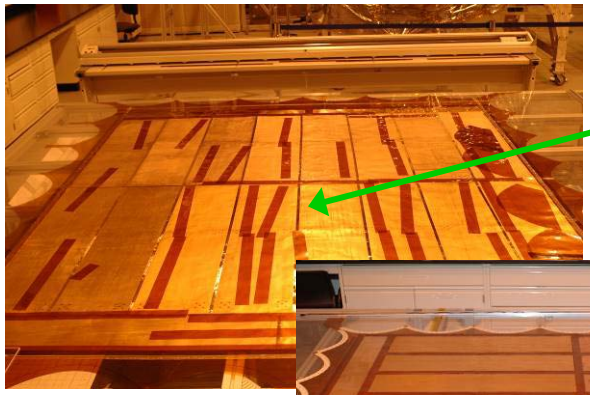
Alignment (using divider panel)

Match Cut

Adhesively Bond (seam) – w/jumpering and backside groundplane attach.



Alignment Marks



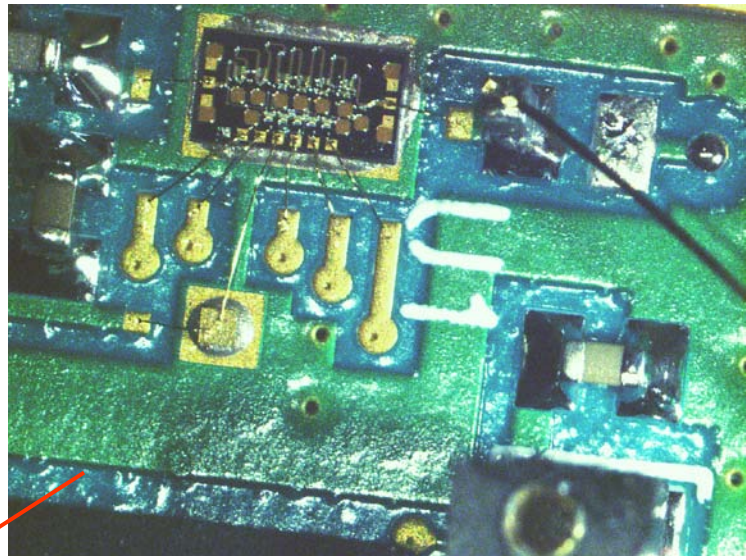
Cu Tape

Kapton w/adhesive

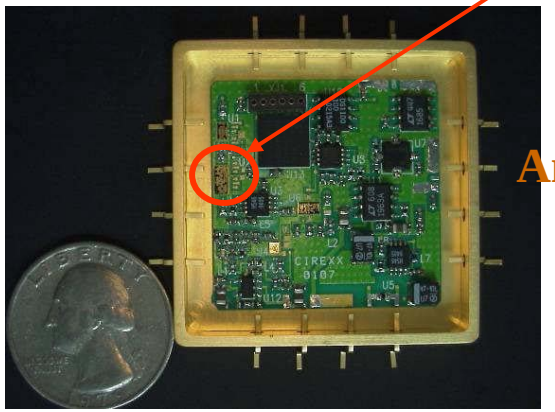
TR Module Development

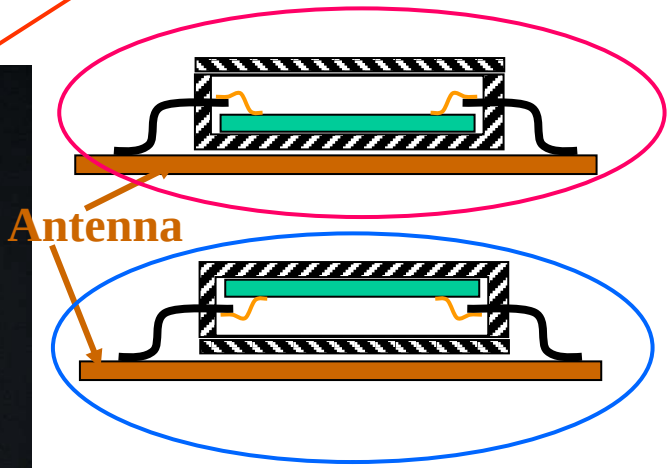
T/R Module Overview

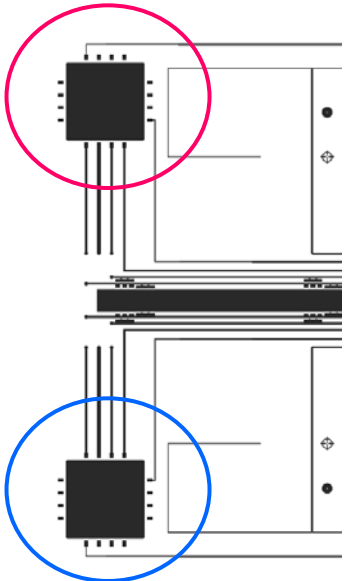
- Technical Specifications **(increased capabilities):**
  - Frequency: 1220 MHz – 1300 MHz
  - Bandwidth: 80 MHz
  - **Tx Peak Power: 33dBm (2W)**
  - 360° phase coverage with 5.6° LSB
  - 23dB maximum attenuation with 0.75dB LSB
  - 15 - 18dB transmit gain (with 13dBm input power)
  - 10 - 12dB receive small-signal gain
  - **Voltage regulation**
  - **Energy storage subsystem**
  - 1.24in x 1.24in board size on polyimide



- **Miniaturize TR**
  - Hybrid design, components are in die form when possible
  - Number of layers increased to place DC and RF on separate layers







Membrane Compatible T/R Module Block Diagram

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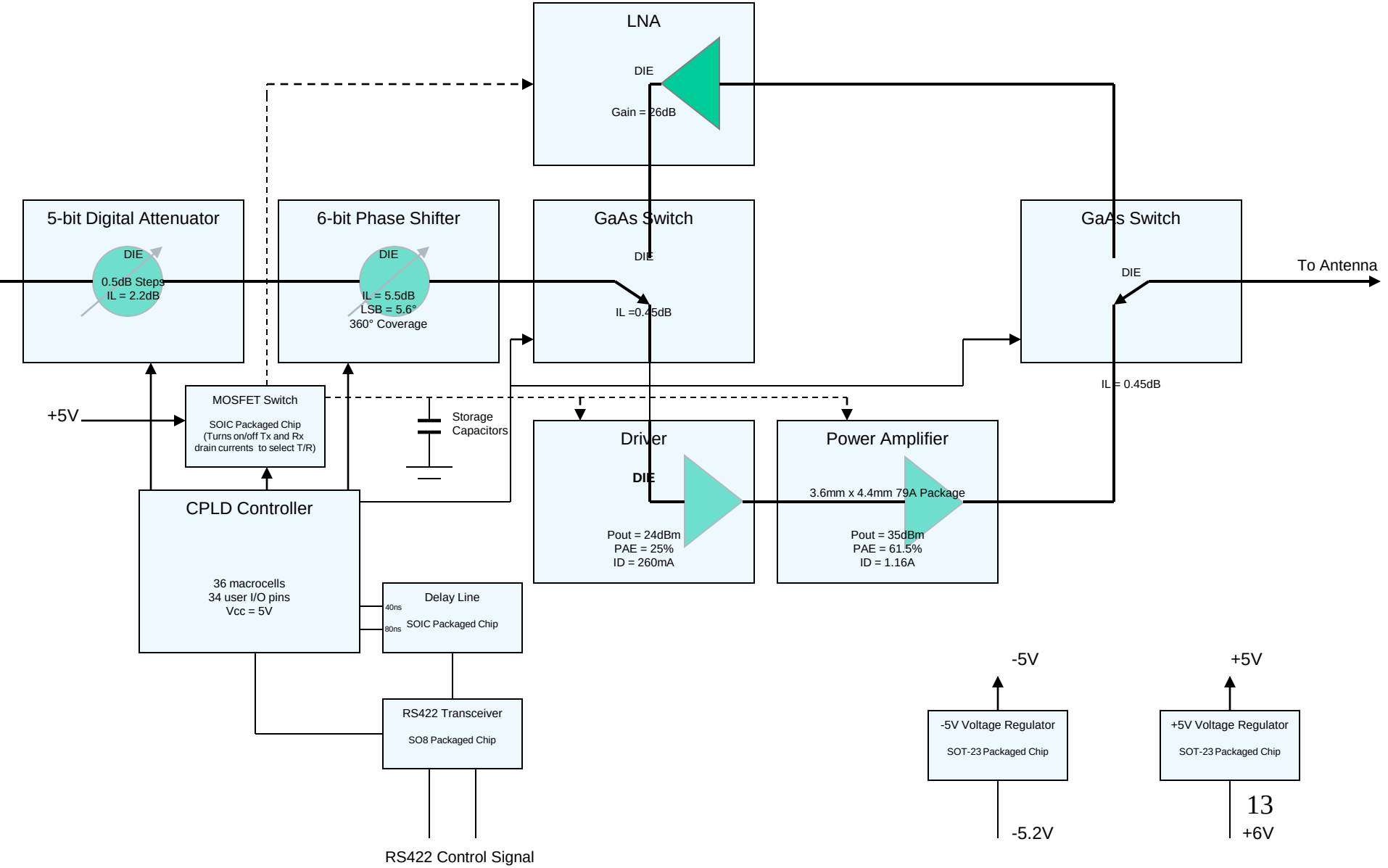
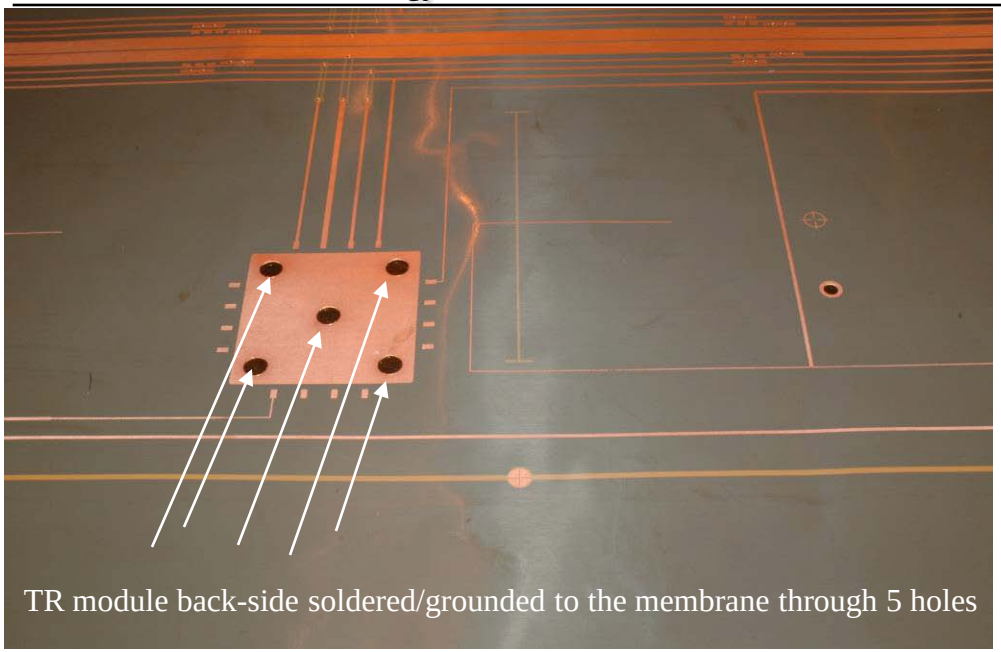
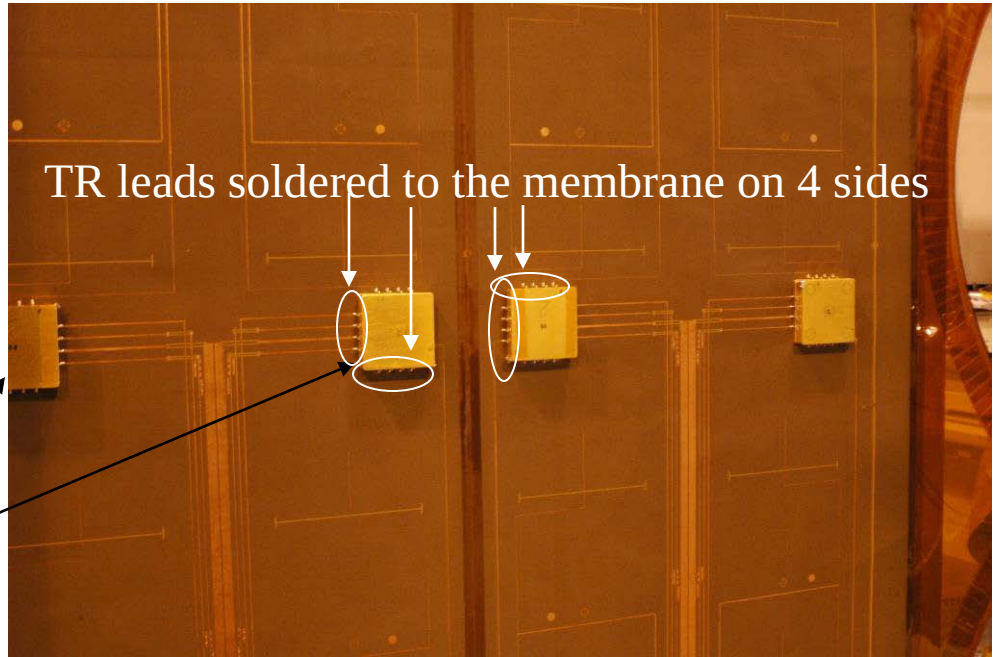


TR Module Installation Process

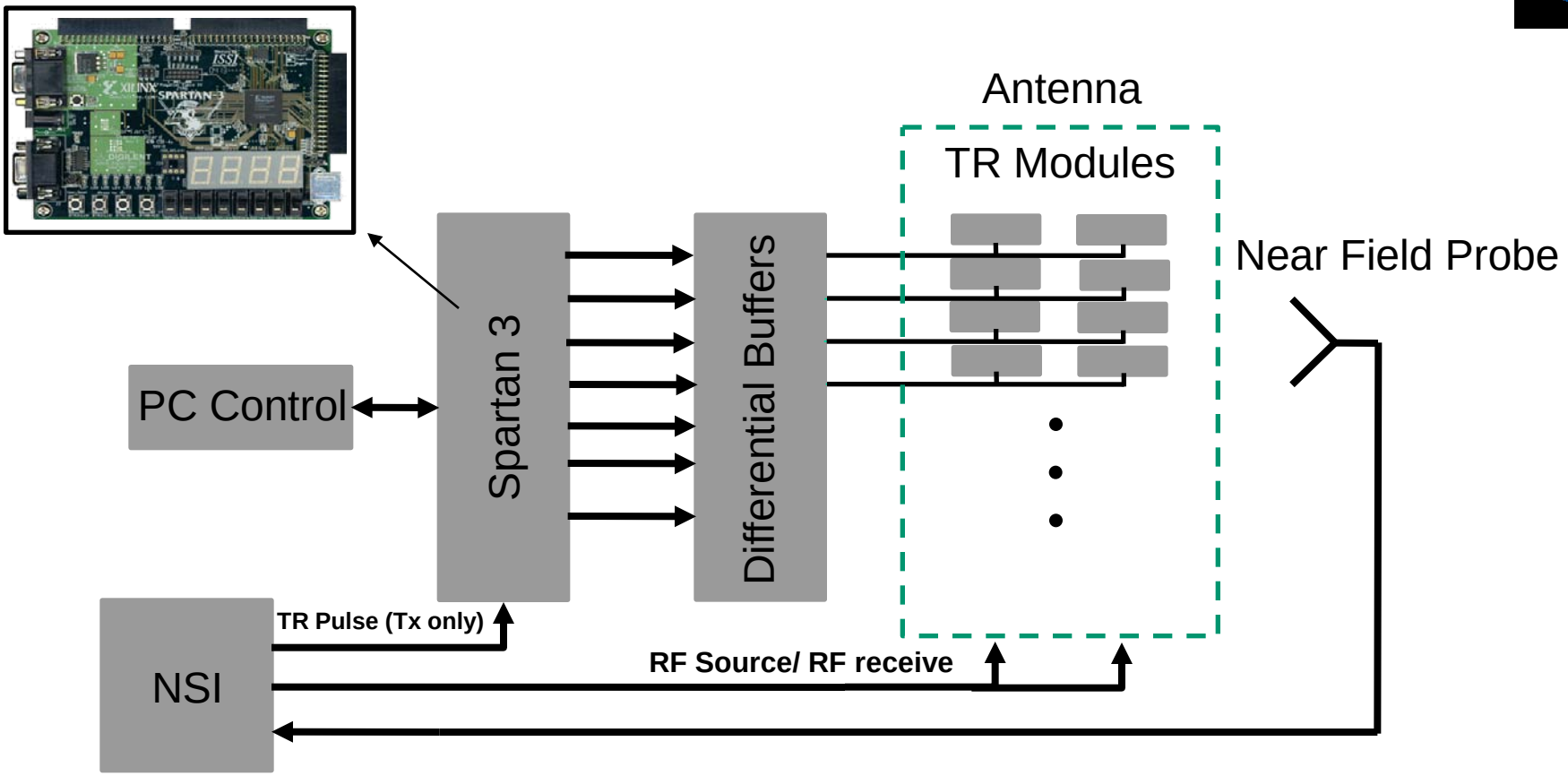




TR Modules attached

Active Antenna Measurements

Test Setup Diagram



Antenna Measurement using Near-field Scanner

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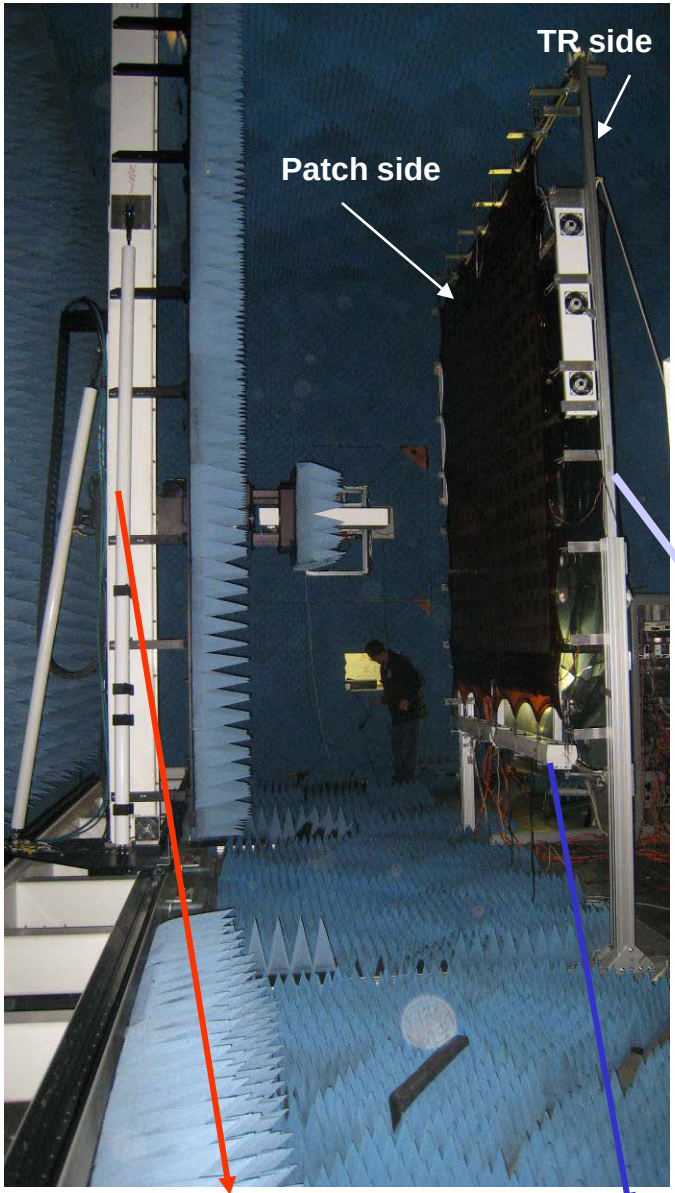
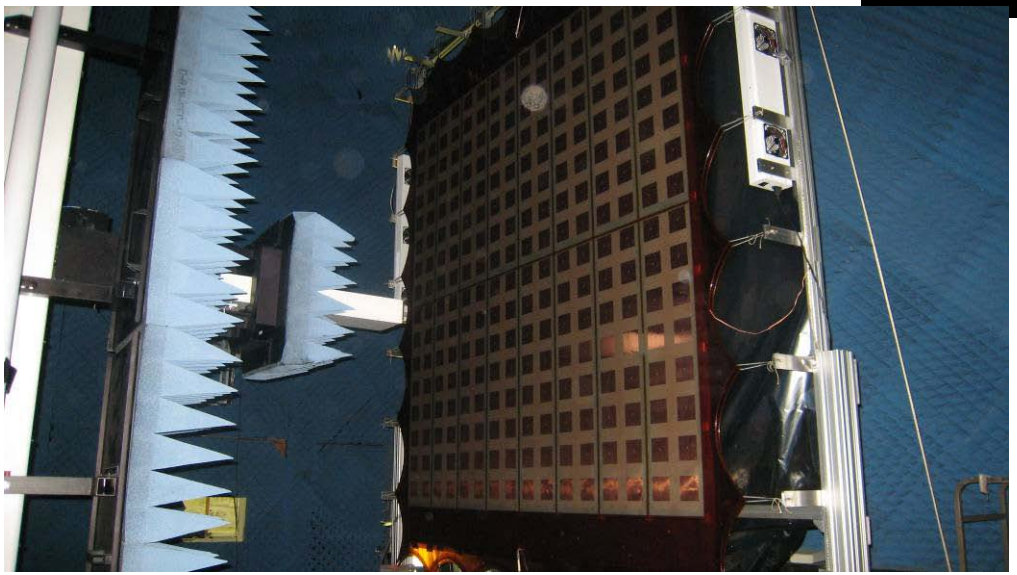
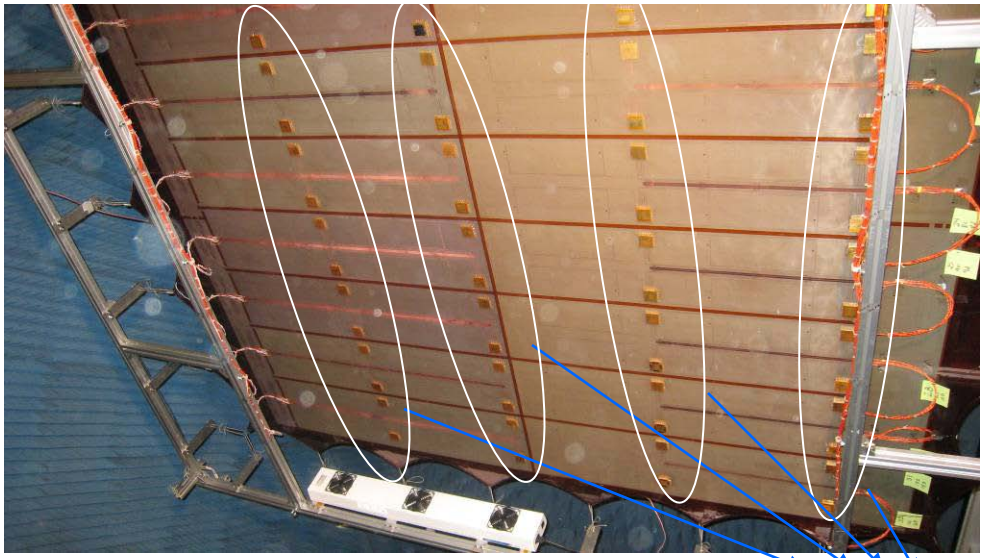




Antenna Patch-side



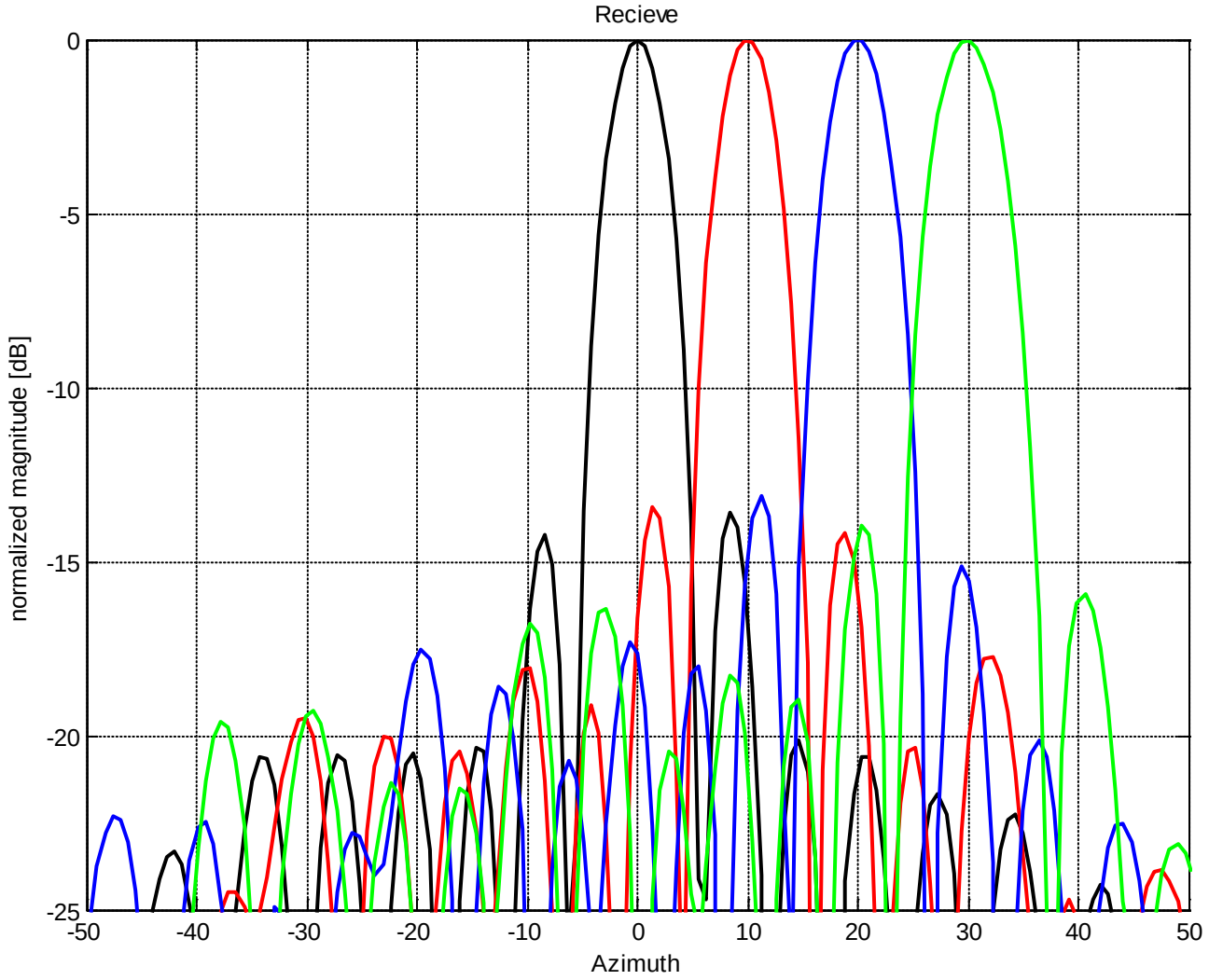
Nearfield Scanner

Membrane antenna

Antenna TR-side

TRs

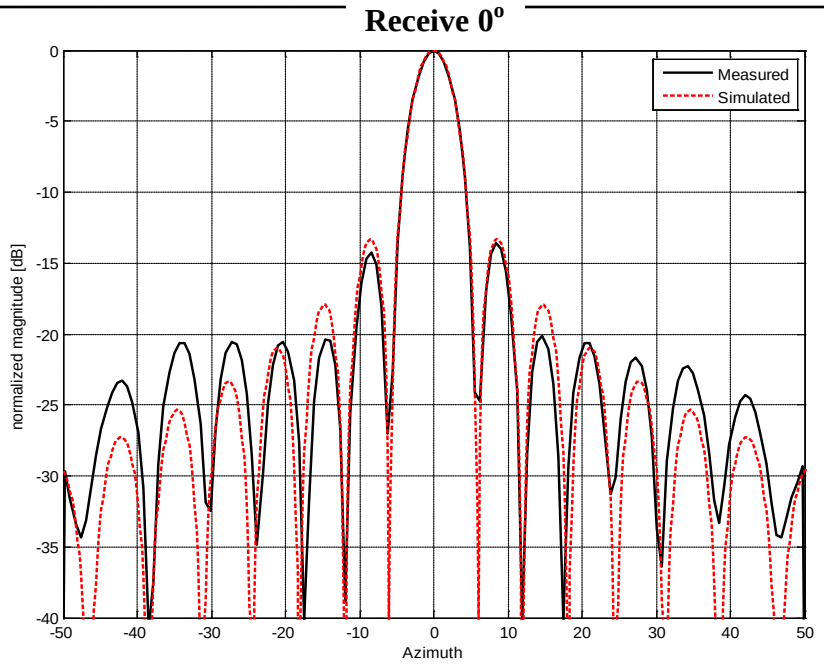
Normalized Receive Patterns (H-plane)

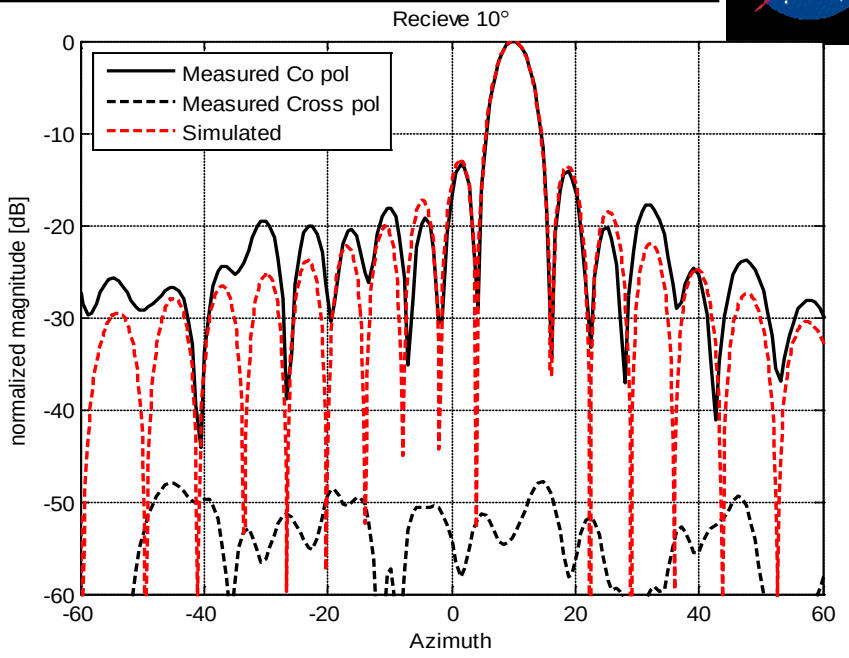


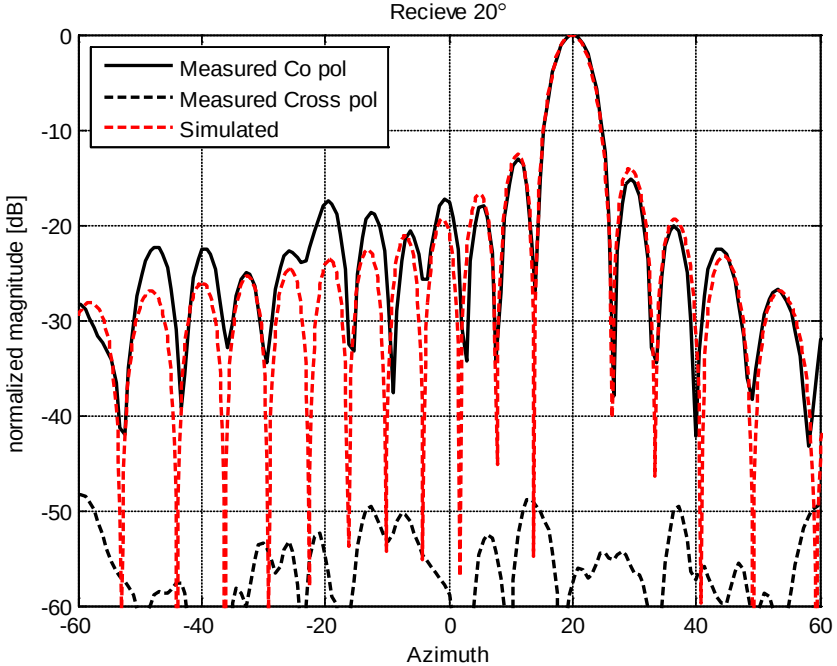
The antenna beam is electronically scanned from 0° to 30° using the TR module phase shifter

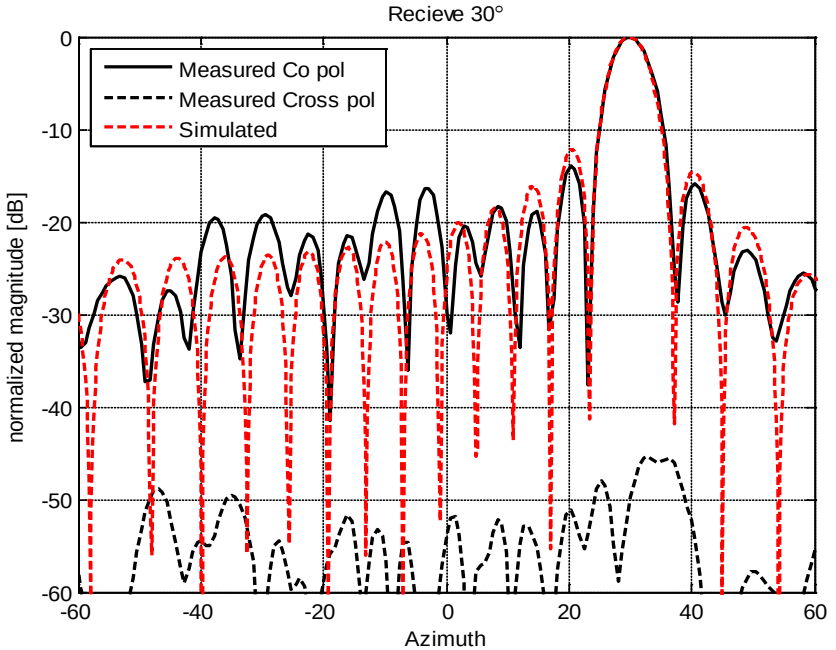
Rx Gain at 0deg: 30dB

Measured vs. Simulated Patterns



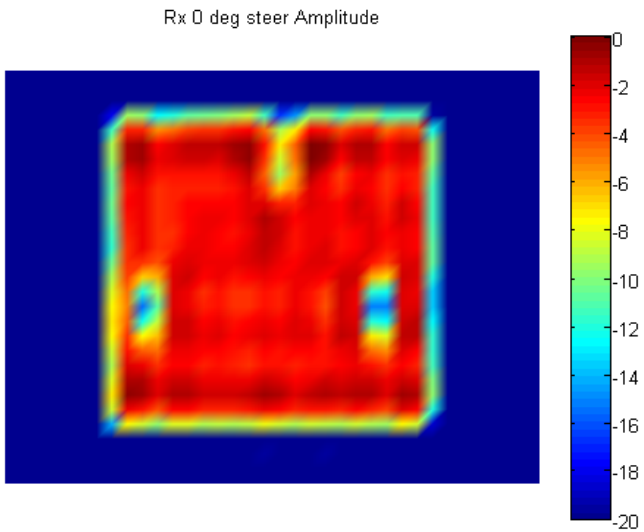






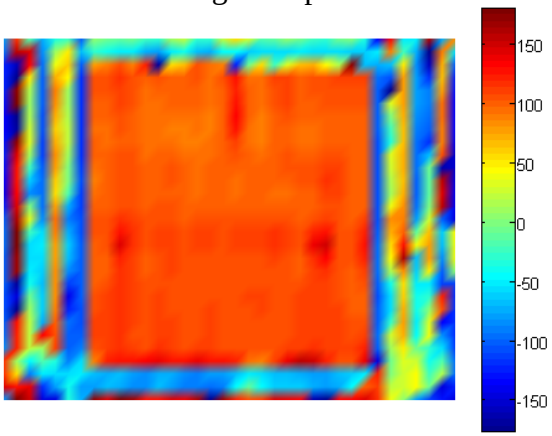
Receive Holograms

Amplitude

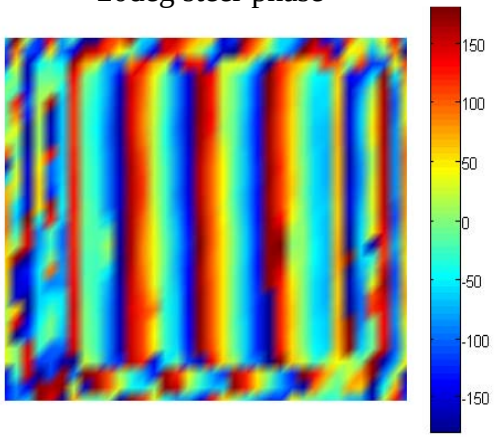


Phase

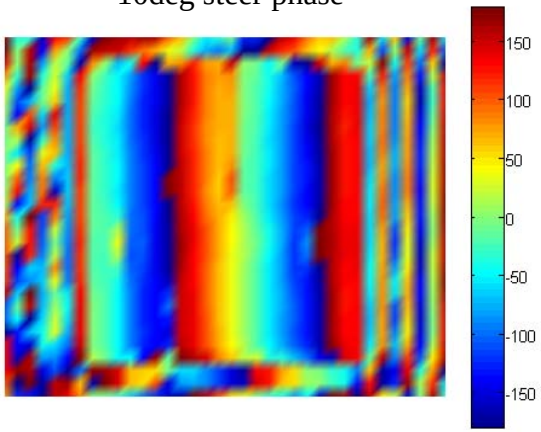
0deg steer phase



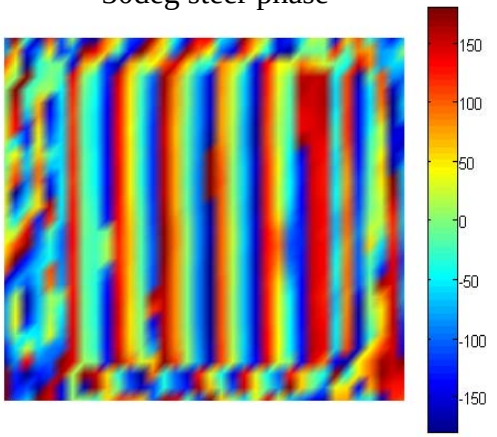
20deg steer phase



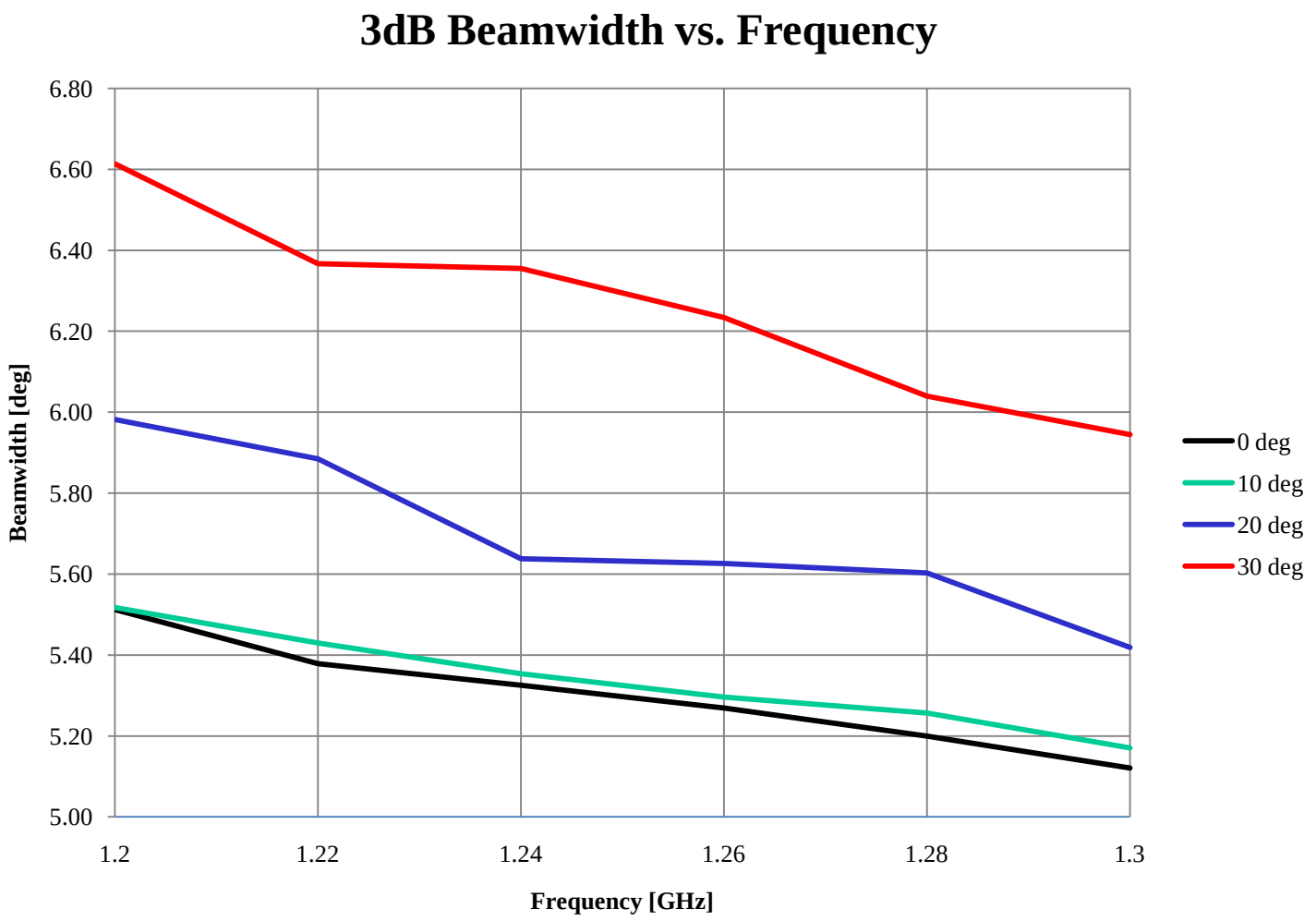
10deg steer phase



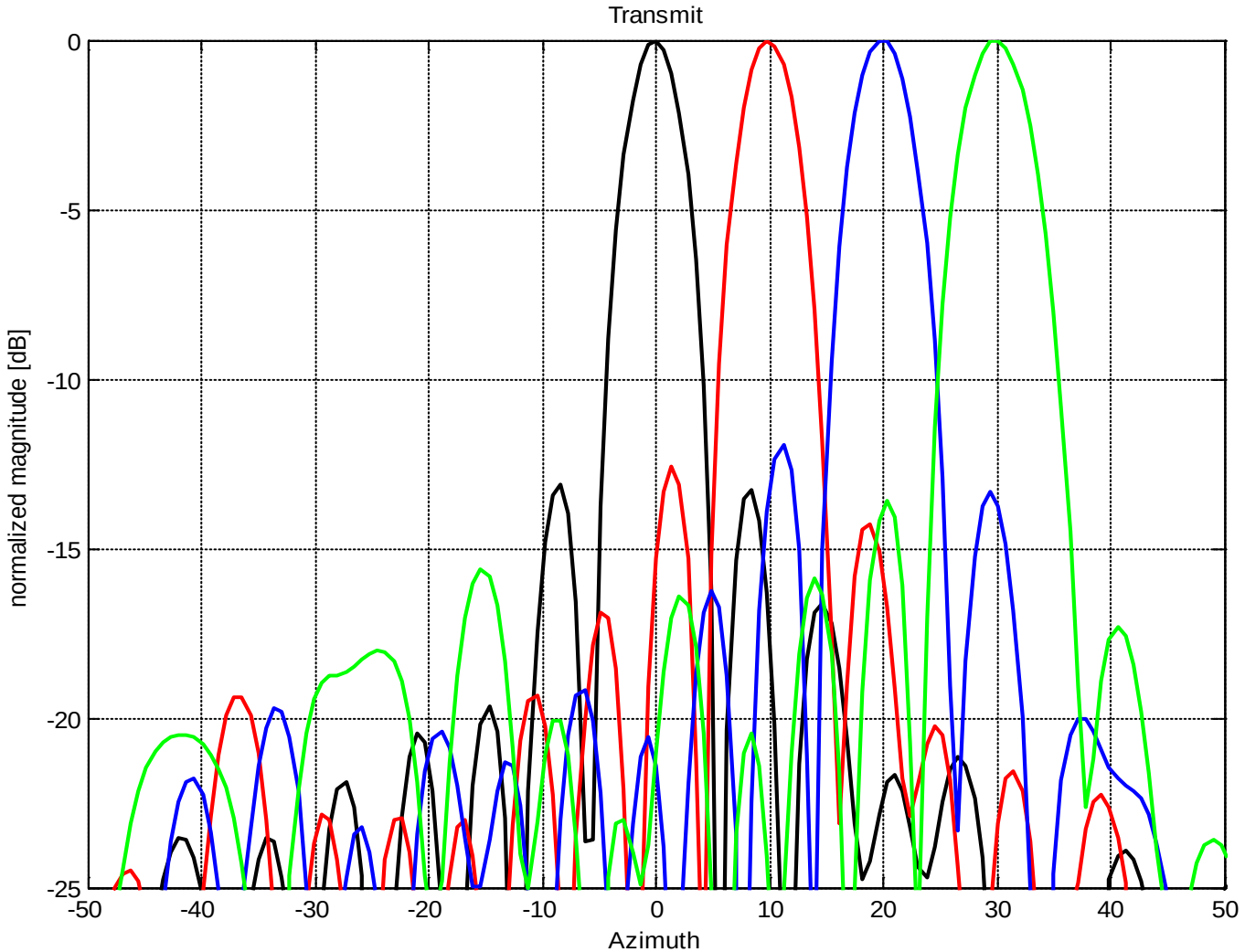
30deg steer phase



3 dB Beam width vs. Steer Angles



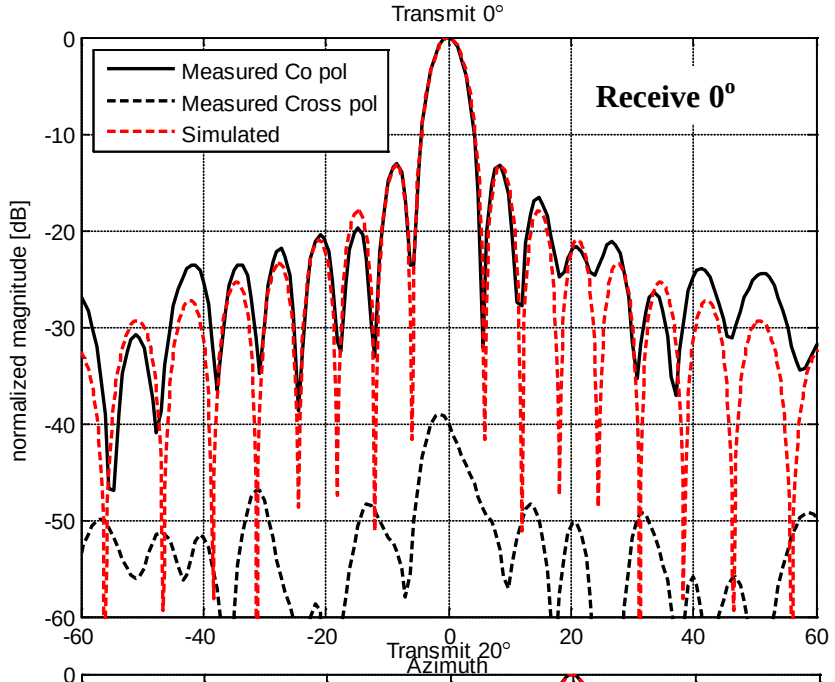
Normalized Transmit Patterns (H-plane)

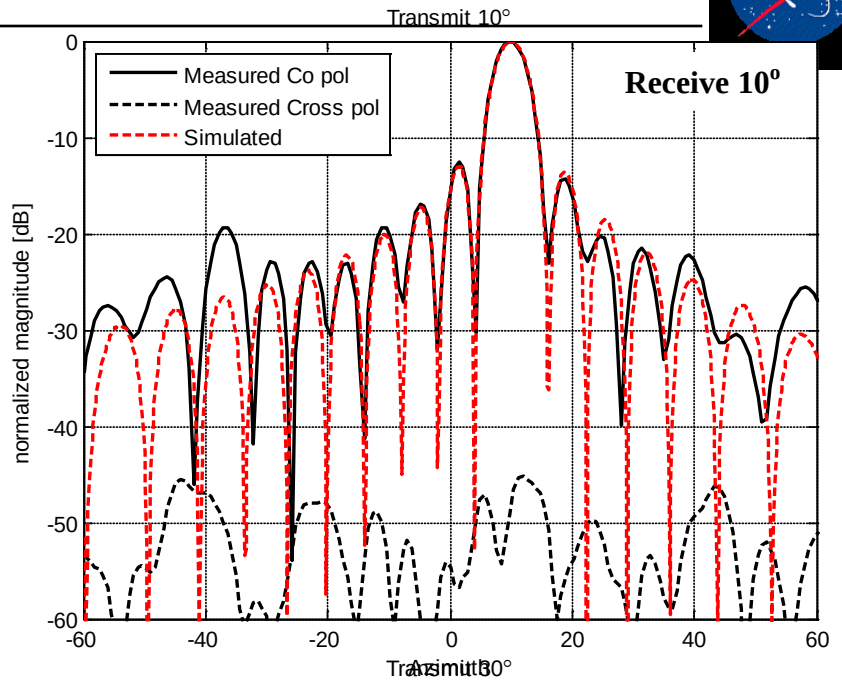


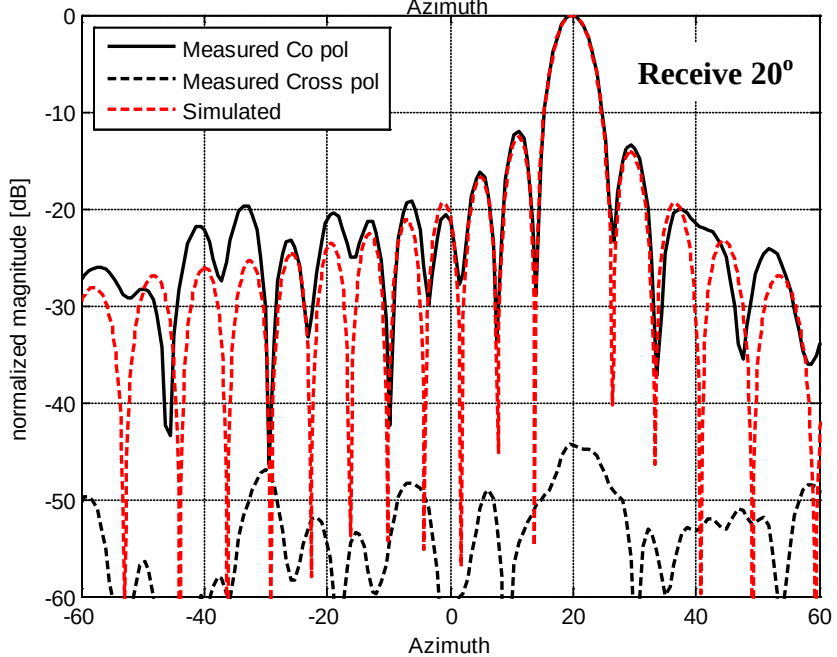
The antenna beam is electronically scanned from 0° to 30° using the TR module phase shifter.

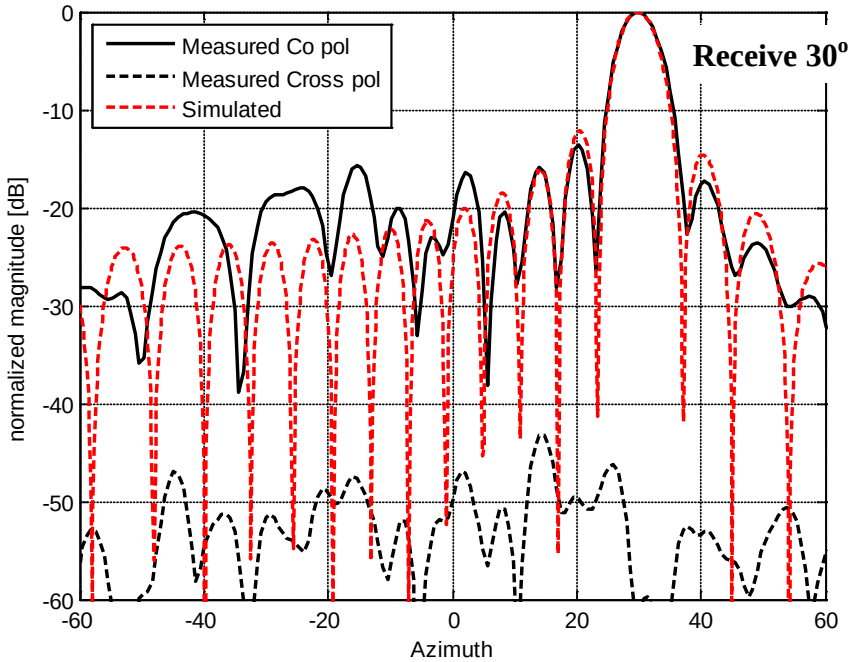
Measured Transmit Gain at 0 deg: 37dB

Measured vs. Simulated Patterns



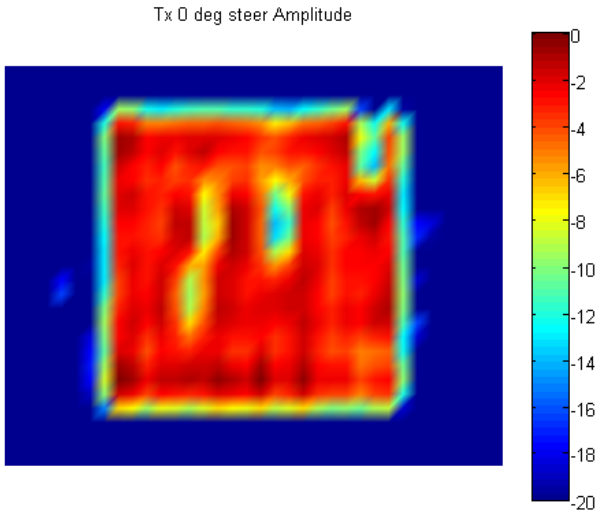






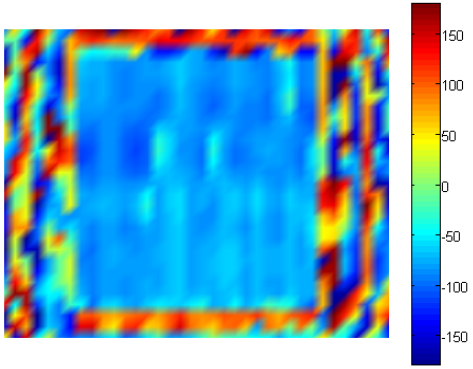
Transmit Holograms

Amplitude

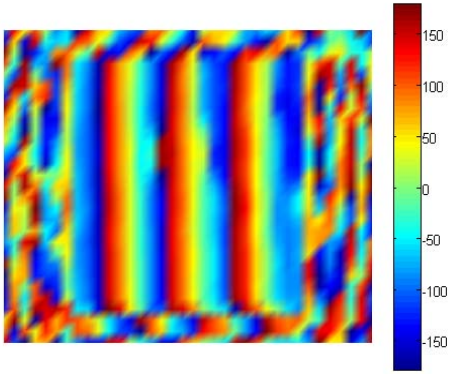


Phase

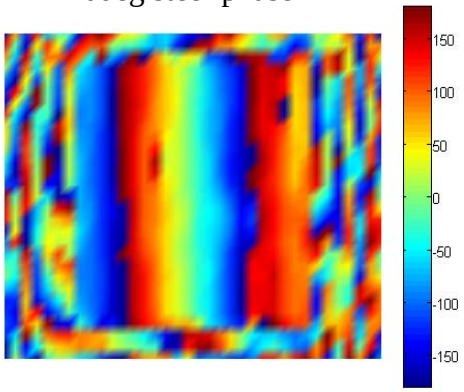
0deg steer phase



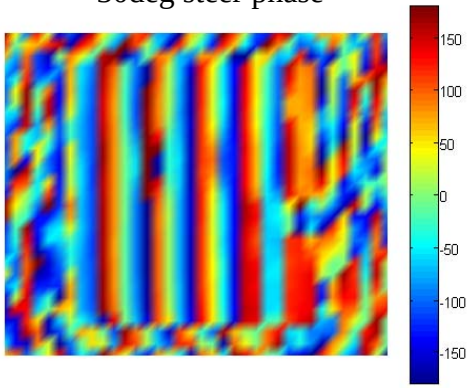
20deg steer phase



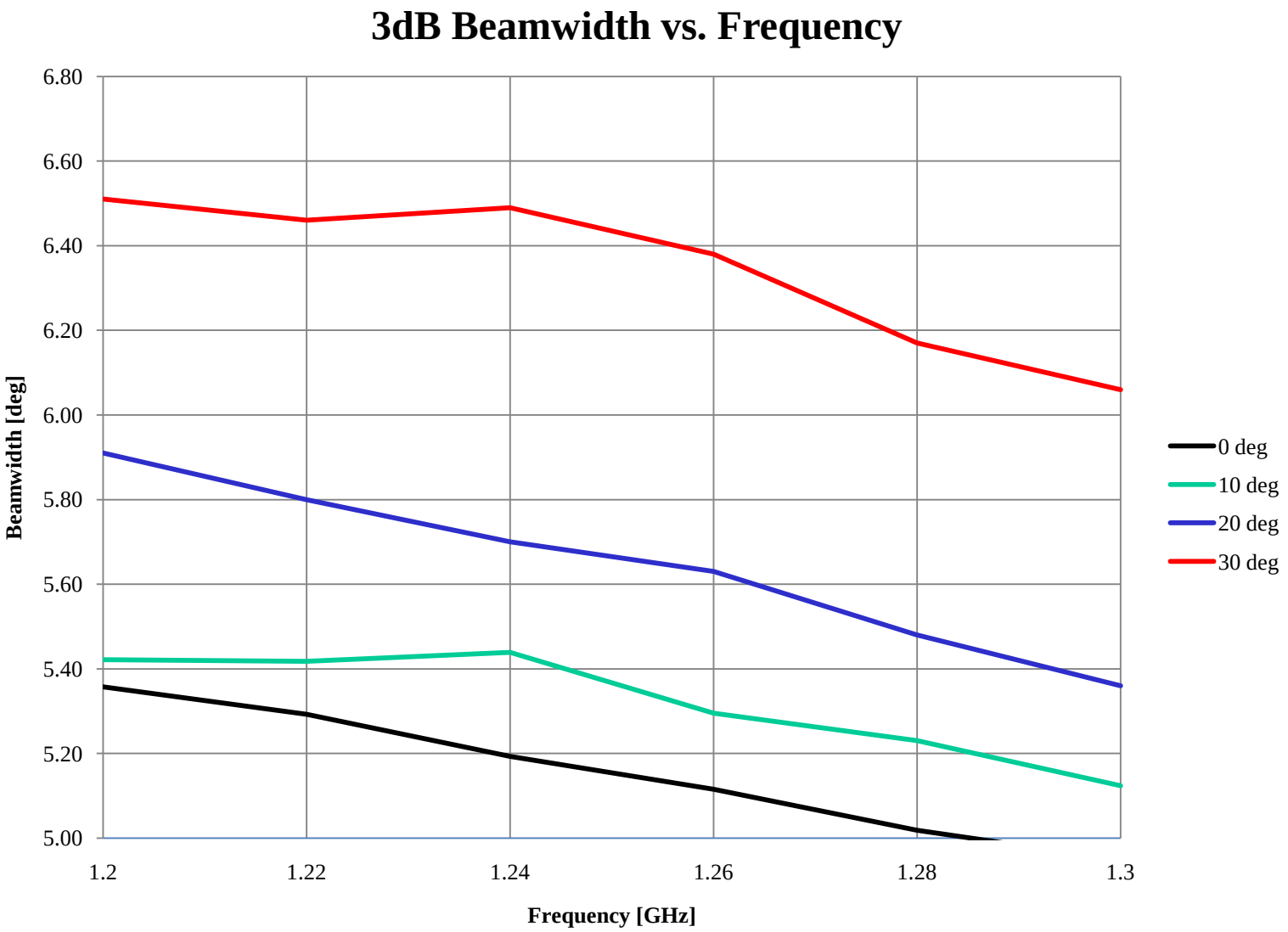
10deg steer phase



30deg steer phase



3 dB Beam width vs. Steer Angles



Conclusions and Future Work

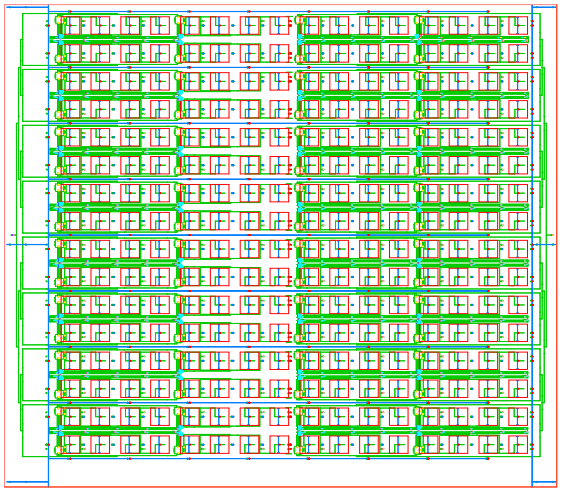
-We developed techniques compatible with construction of multi-layer large active membrane arrays.

- Alignment
- Seaming
- Routing of DC/control and RF signals

- We developed miniaturized membrane-compatible T/R modules.
- We demonstrated a 16x16 element active array to evaluate the manufacturing techniques and the array design.

-To further develop membrane-based phased array technology we need to address

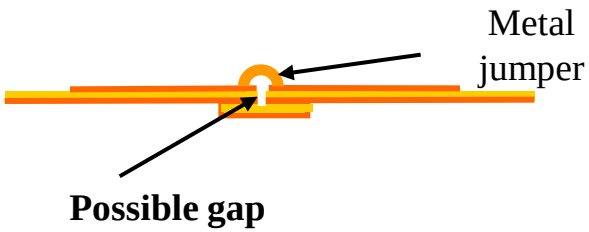
- Antenna deployment System.
- Integrated divider design instead of the 16 way divider used here.

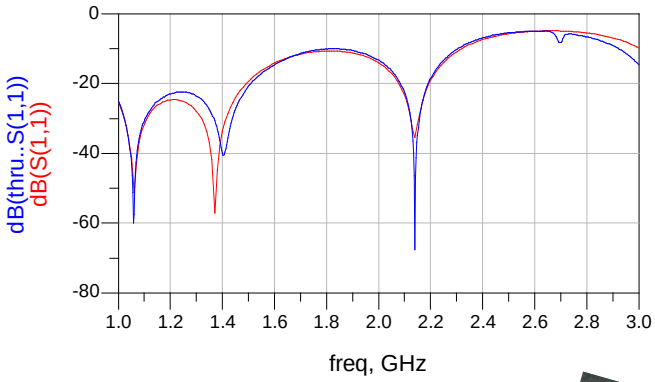


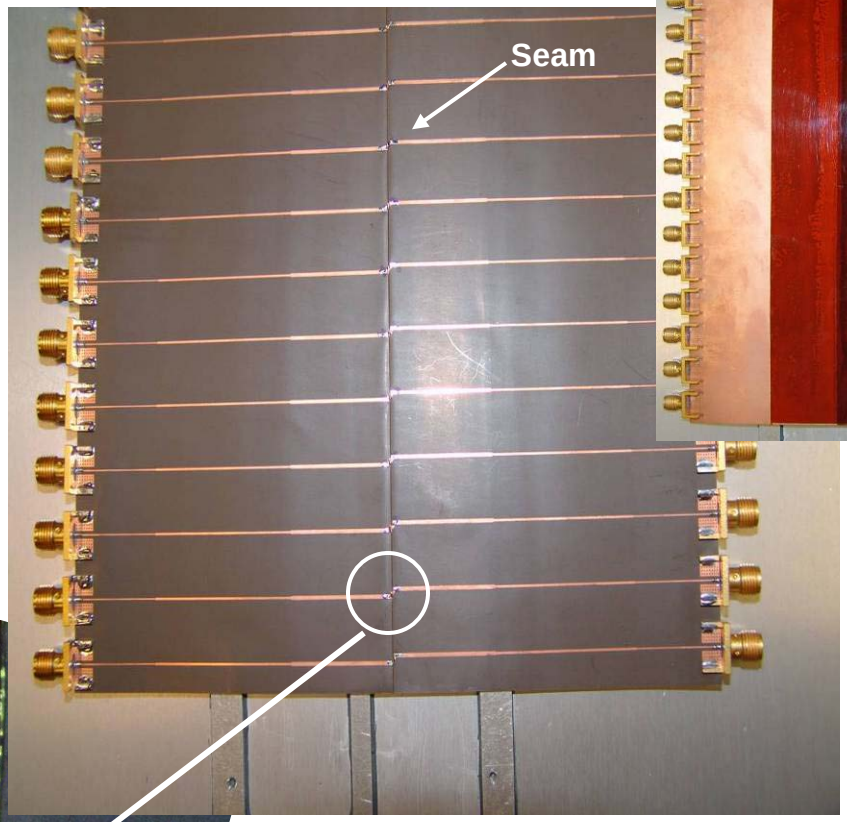
Backups

Seaming/Jumpering/Misalignment Experiments

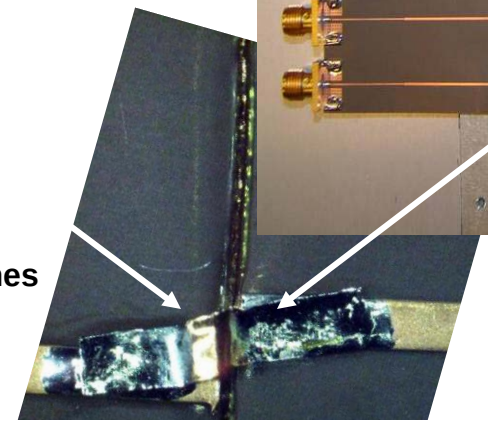
California Institute of Technology







Backside showing the seam

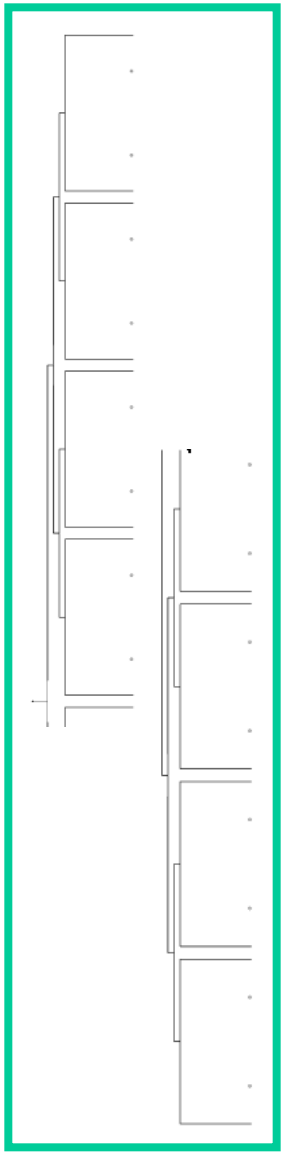


Misaligned miscrostrip lines with jumpers

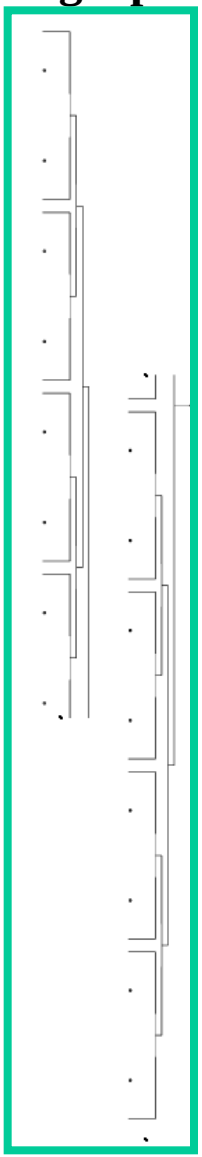
Misaligned miscrostrip lines with seam and jumpers

Board Layout (Blow-up)

The following 6 panels (8 designs) comprise the building blocks of the 16 x16

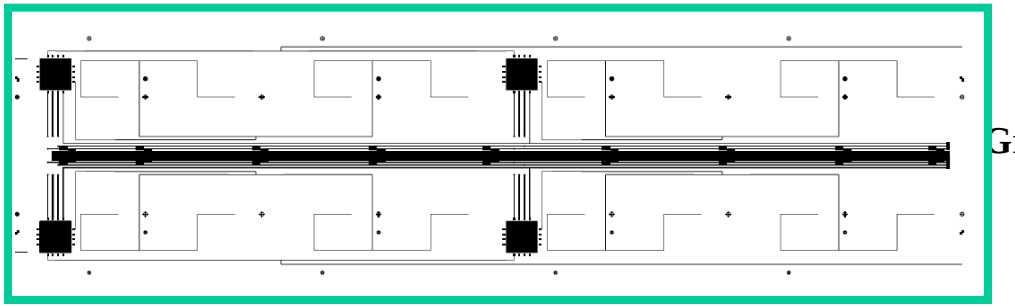


Feed (left)

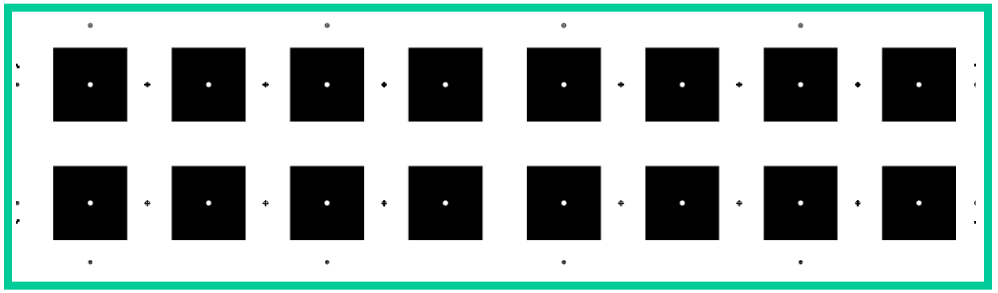


Feed (right)

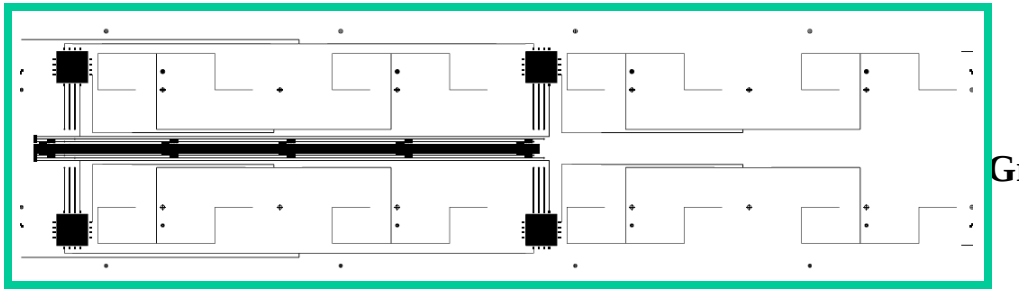
4 unique divider designs



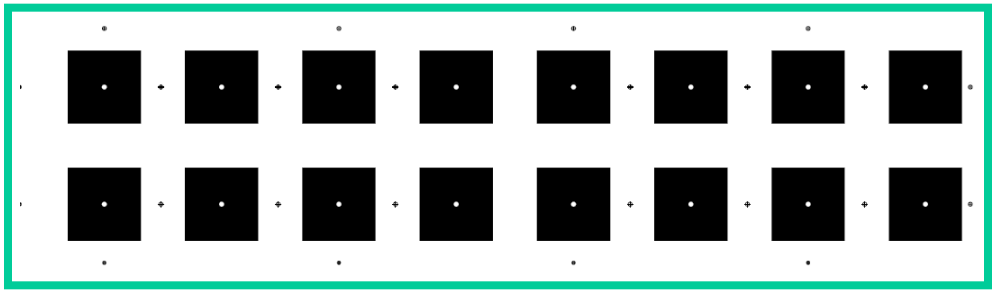
Ground/TR (right)



Patch (right)

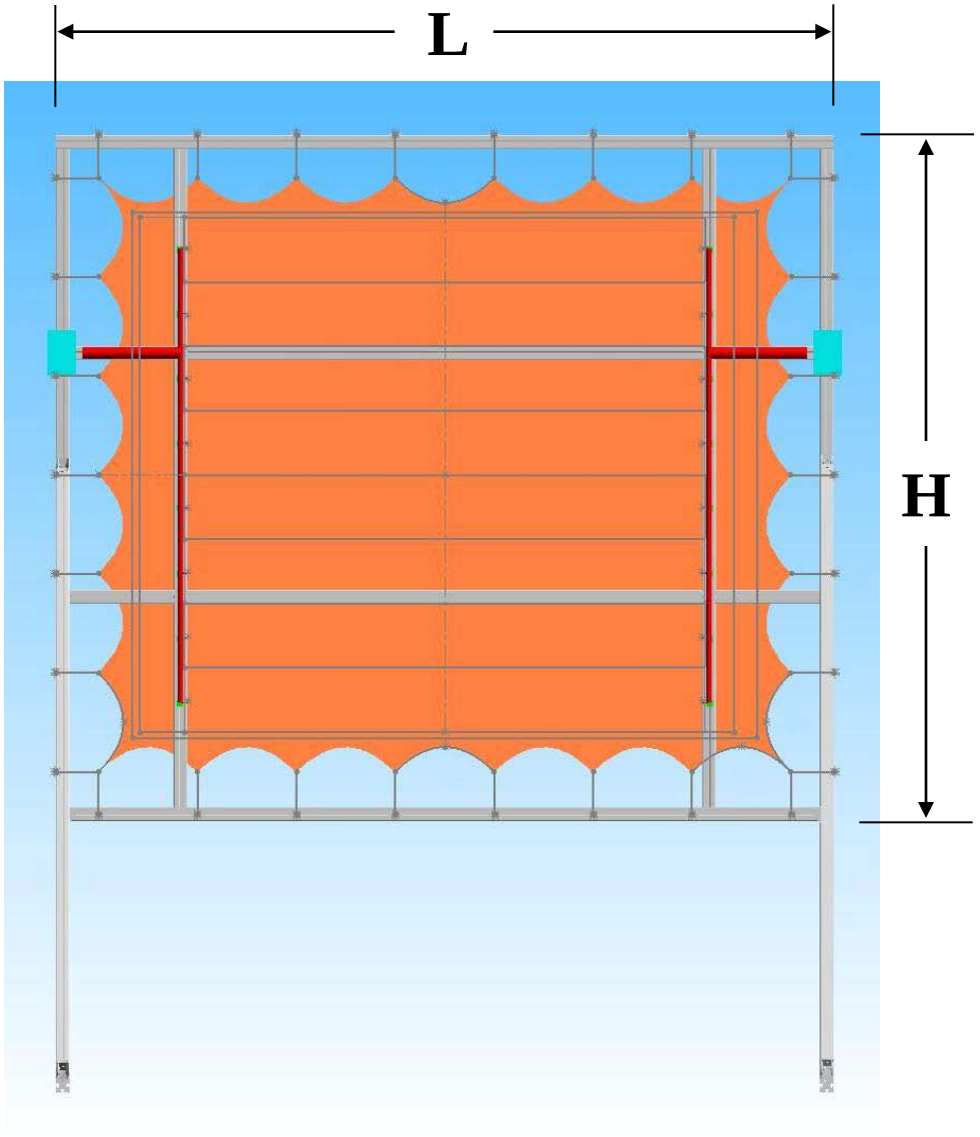


Ground/TR (left)



Patch (left)

16x16 Active Array Dimensions



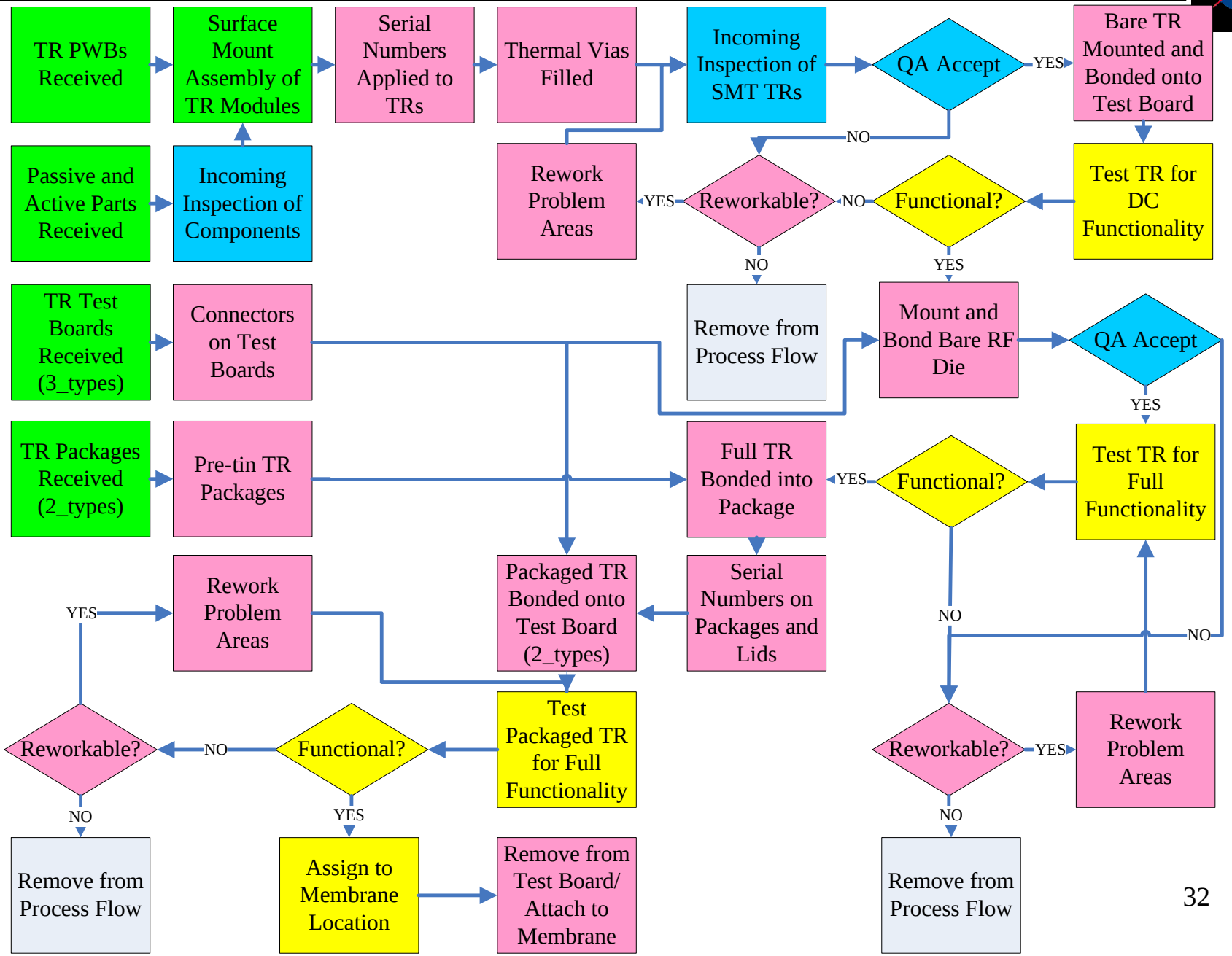
Overall Dimensions

	Length (L)	Height (H)
Active	90.5 in (2.3 m)	90.5 in (2.3 m)
Catenary	121.5 in (3.09 m)	104.5 in (2.65 m)
Frame	143.5 in (3.64 m)	121.5 in (3.09 m)

Assembly of TR Modules

- TR fabrication Steps:
  - TR boards were sent to an SMT house for assembly (all parts except die components)
  - Upon return to JPL the TRs were placed on a connectorized test board for its first DC check and programming of the CPLD
  - Following DC test, the TR die components were attached and wire bonded.
  - The complete TR modules were then RF tested.
  - The TRs were then removed from the temporary test board and packaged (the module was attached to the metal package using a conductive epoxy and the TR I/O were bonded to the package leads). As mentioned in the next slide, the modules were placed in one of two possible package configurations. The package was then soldered onto another temporary test board to facilitate testing. Depending on the package (right-side-up or up-side-down) a different test board was used.
  - The TRs were then mounted on another test board. Depending on the TR type, (right-side-up or up-side-down), we used a different type of test board.
  - Assigned locations on the array. Depending on the location remove internal TR communication termination resistor in half of the TRs
  - Addressed the TRs depending on the TR location on the array

TR Module Process Flow

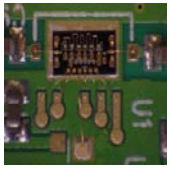


TR Module Process Pictures

TR PWBs Received

Surface Mount Assembly of TR Modules

Serial Numbers Applied to TRs

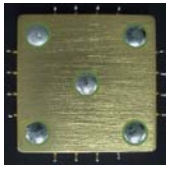


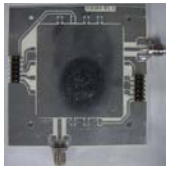
Mount and Bond Bare RF Die

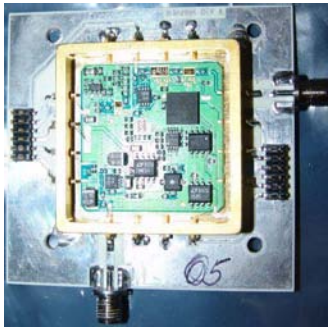
Full TR Bonded into Package

TR Packages Received (2_types)

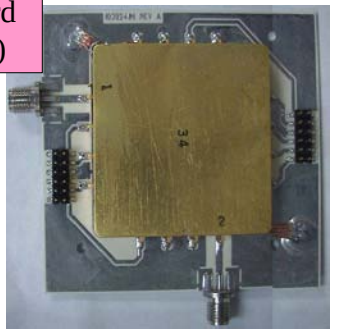
Pre-tin TR Packages



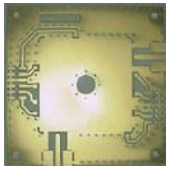




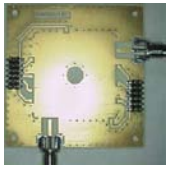
Packaged TR Bonded onto Test Board (2_types)

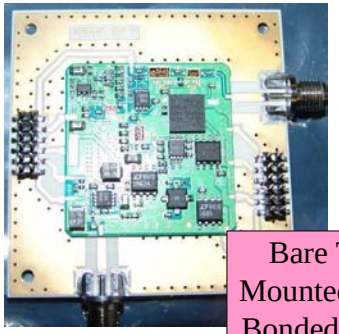
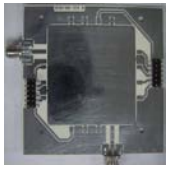


TR Test Boards Received (3_types)



Connectors on Test Boards





Bare TR Mounted and Bonded onto Test Board