# Compact Dual-Frequency Dual-Polarization Microstrip Antenna Feed for Future Soil Moisture and Sea Surface Salinity Missions


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# Outline

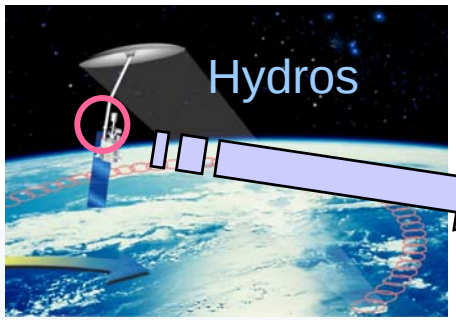
- Introduction
- Technical Development
  - Stacked-patch design
  - Antenna Design Trades
  - Feed Network Design and Prototype
- Summary
- Next Step Plan

# Lightweight Dual-Frequency Microstrip Antenna Feed for Future Soil Moisture and Sea Surface Salinity Missions

- **Objective: Develop a compact dual-frequency antenna feed for future soil moisture and sea surface salinity missions**

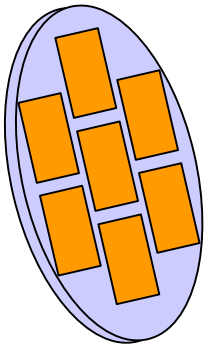
**Enables**: Compact, lightweight antenna feeds for operational soil moisture and ocean salinity radar/radiometer missions

**How**: Develop a dual-frequency microstrip antenna feed
- Reduce the length of feed from 1.2 m to 0.1 m
- Reduce mass from 15kg to 2kg per antenna feed

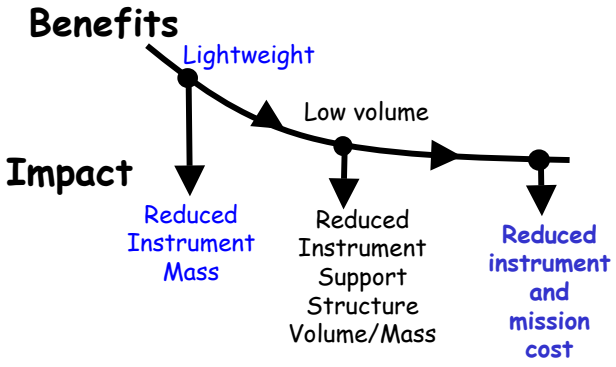




Conical Feedhorn, Orthomode Transducer, and Frequency Diplexer Assembly
- 1.2 m long
- 15 kg mass



Dual-frequency Microstrip Stacked-Patch Array
- >0.1 m profile
- >2 kg

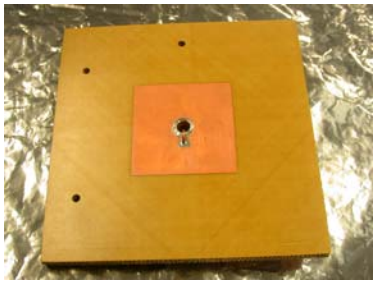


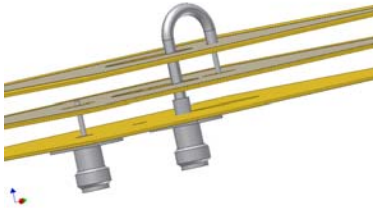

**Selected NASA ESSP-3 Missions**

# Development Plan

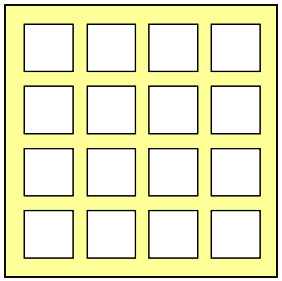
2003 (Phase 1) 2004 (Phase 2) 2005 (Phase 3)

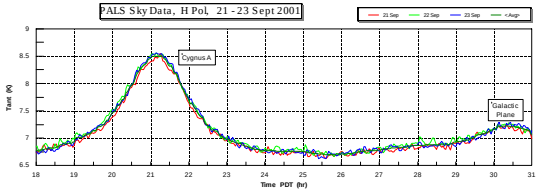
- Design and testing of a single microstrip stacked patch to verify the dual-frequency design concept





- Design, fabricate, and test the microstrip array
  - Return loss
  - Radiation pattern

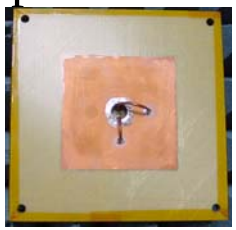





- Measurements of the insertion loss of the MSPA using the cold sky

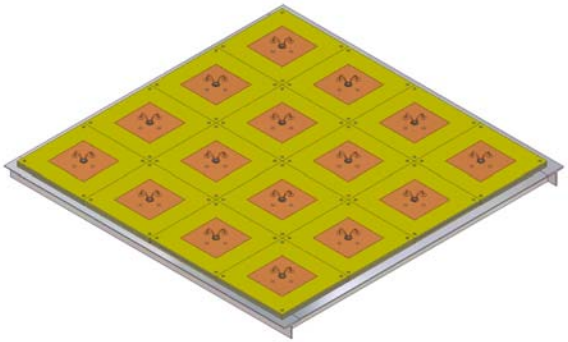
# Phase 2 Plan

- Design modifications for frequency optimization

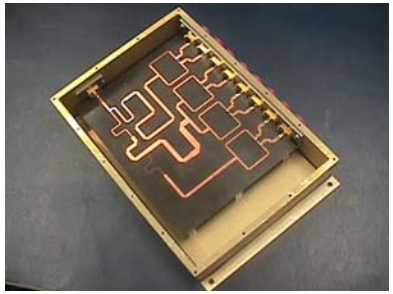


- Element fabrication and testing (V2 and V3)

- Array assembly
- Testing

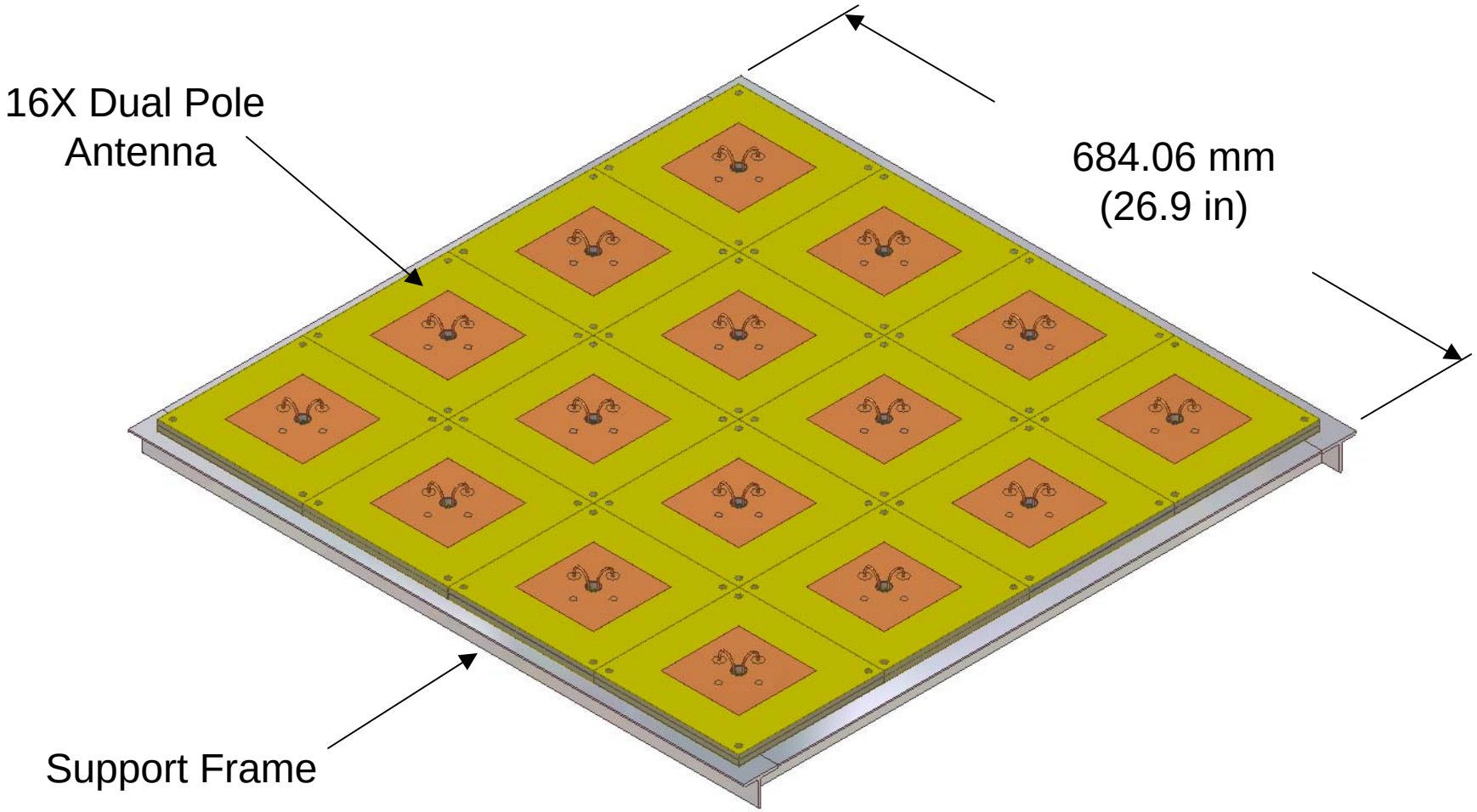


Array design



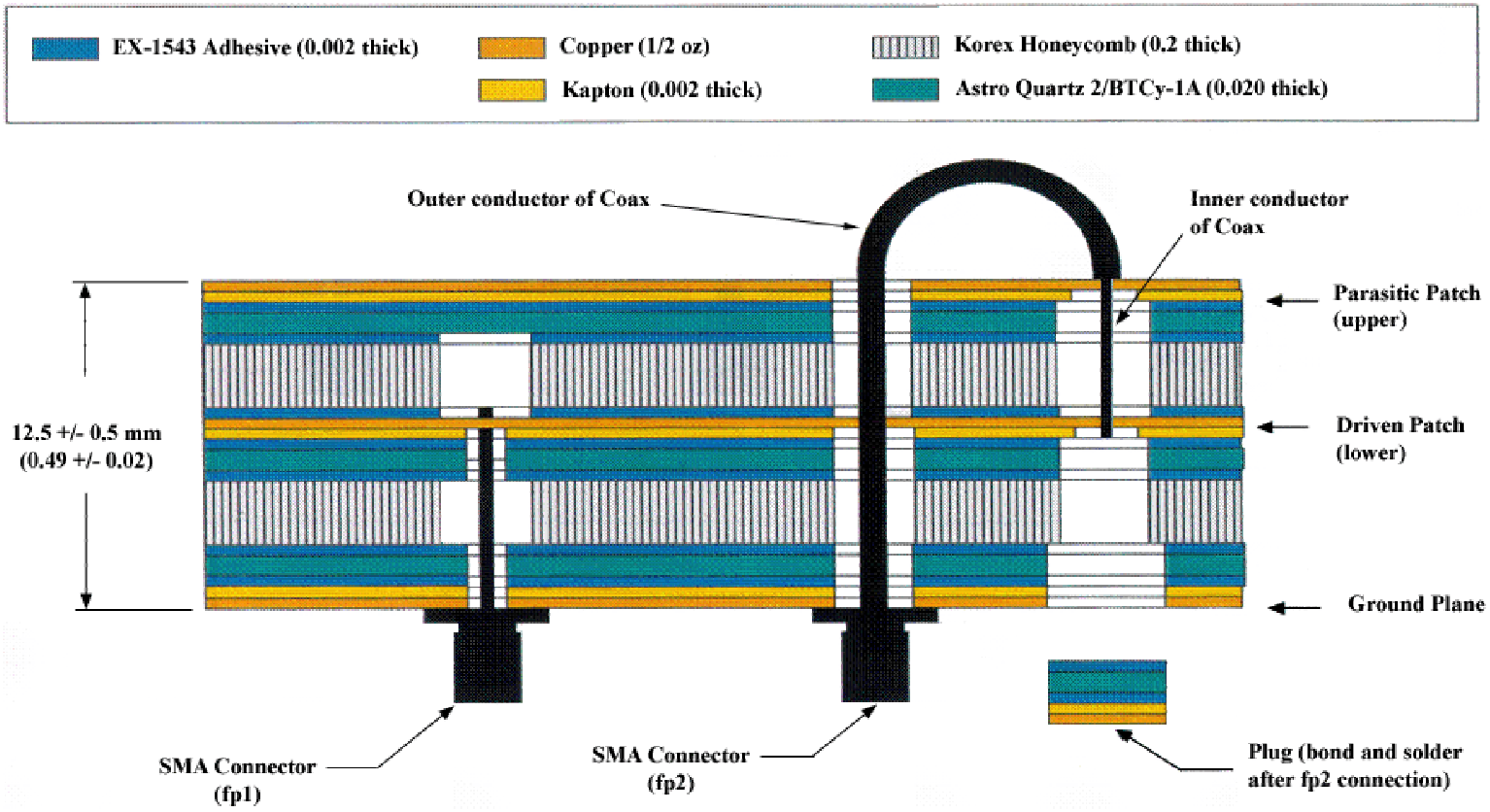
- Power divider design, fabrication and testing
- Frame design and fabrication
- Coaxial cable fabrication

# uSPA Dual Pole 16 Element Antenna Array



# *Stacked Patch Element Design and Testing*

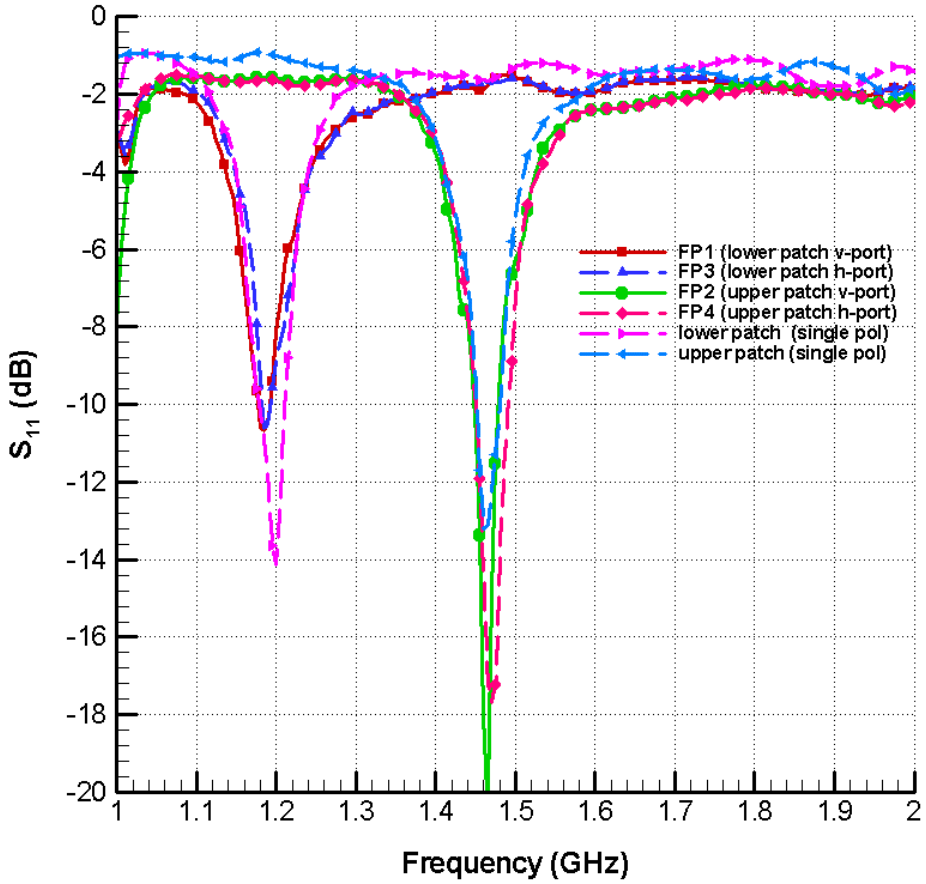
# Side-View of the Stacked Patch Showing the Various Layers

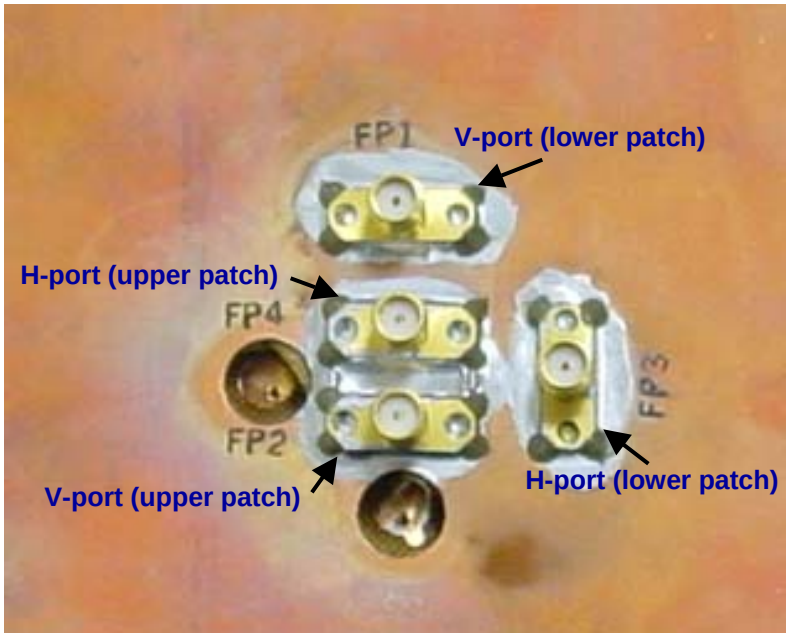



- The various layers were modeled using UCLA-FDTD code
- Effective parameters were calculated by taking weighted average for layers that were too thin

# Return Loss Measurement Results of Dual-Frequency Dual-polarized Microstrip Patch

**Design phase 1**




**Bandwidth (-10dB)**

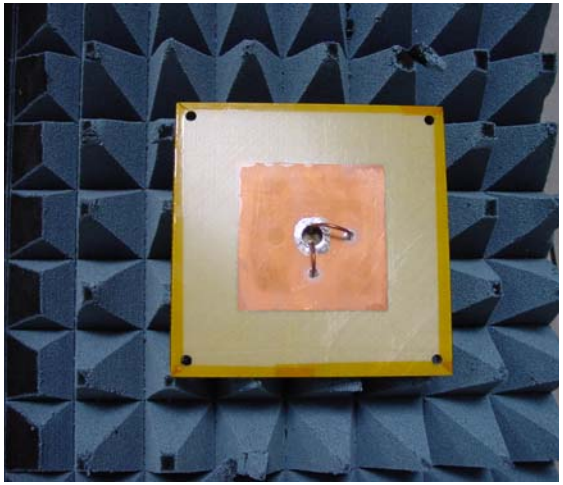
**FP1: 22.5MHz**
**FP3: 20.0MHz**
**FP2: 32.5MHz**
**FP4: 40.0MHz**
**Lower patch (single pol) : 35MHz**
**Upper patch (single pol): 32.5MHz**

## Remarks:

A shift in the resonant frequency was observed from the required frequencies
Shift in lower frequency was 60MHz and shift in upper frequency was 40MHz
We speculate that the reasons are : dielectric constants of the substrates are not known accurately and the FDTD mesh could not be matched to the exact dimensions of the stacked structure.

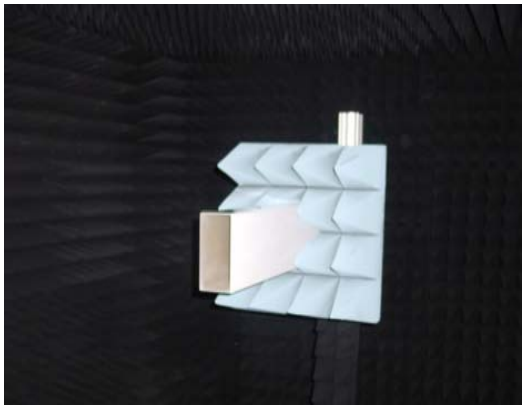
# Stacked Patch Array Element

Design phase 2

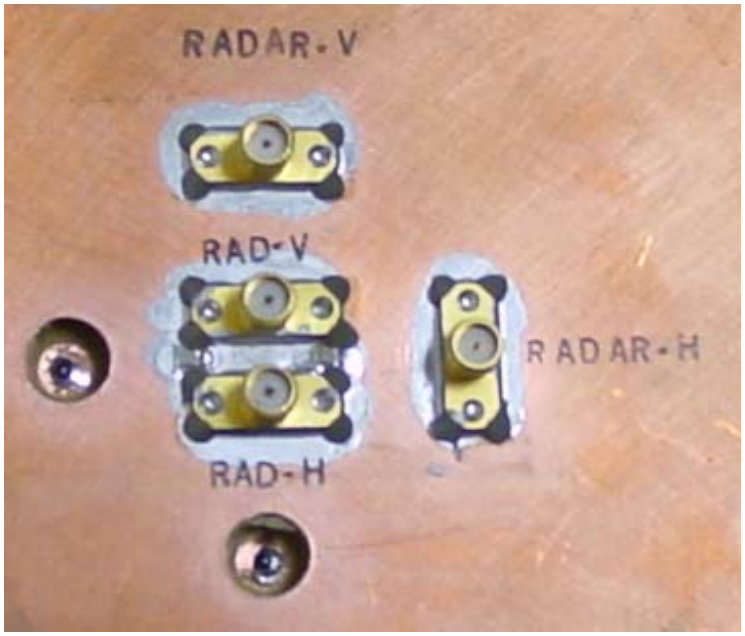


Front-View

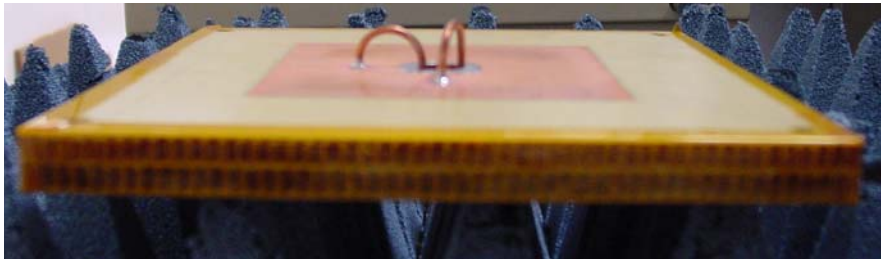
Front-View of stacked patch
(Near-Field Chamber at UCLA)



L-band probe used for measurement



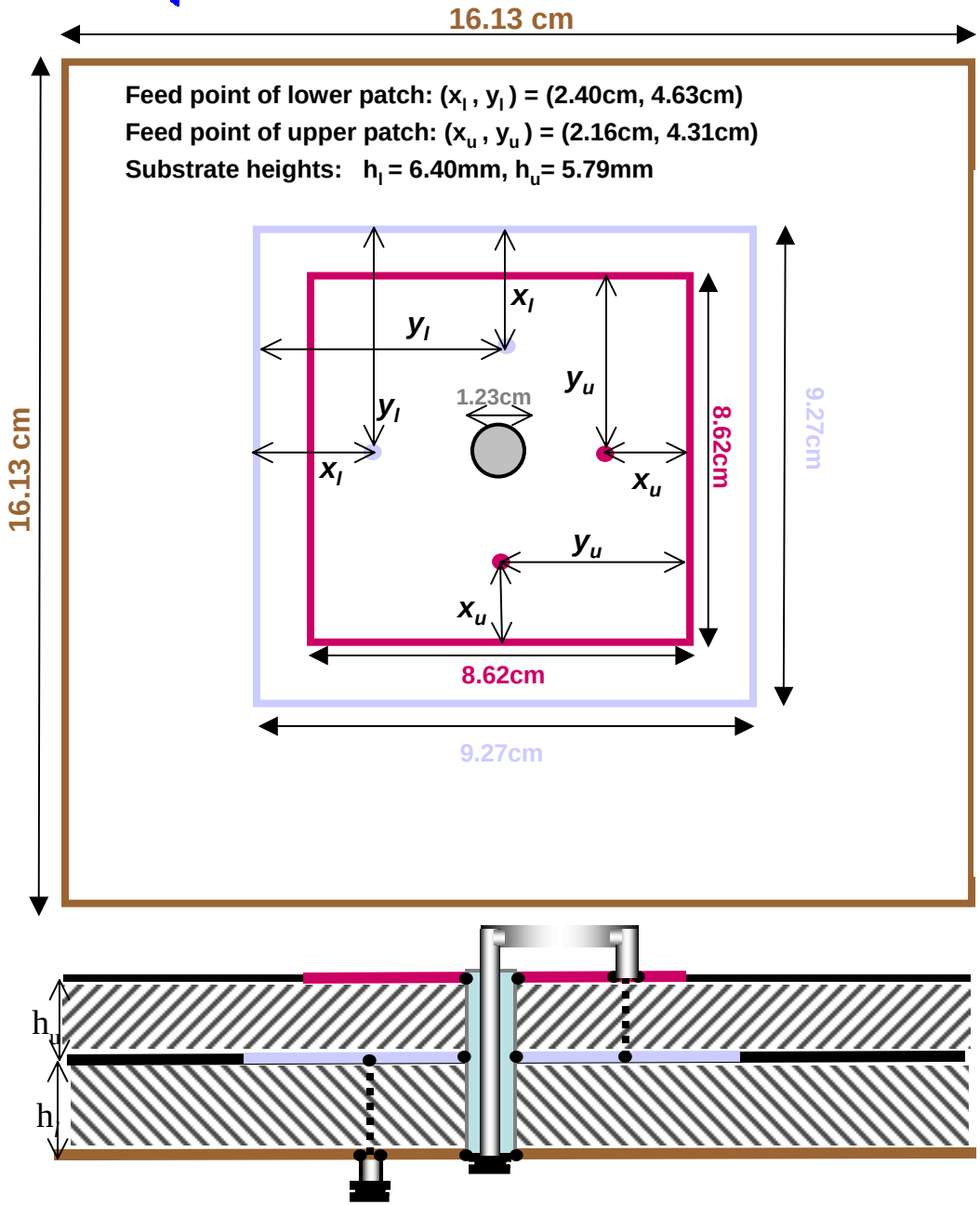

Back-View showing ports



Side-View

# Overhead view of the Stacked Patch

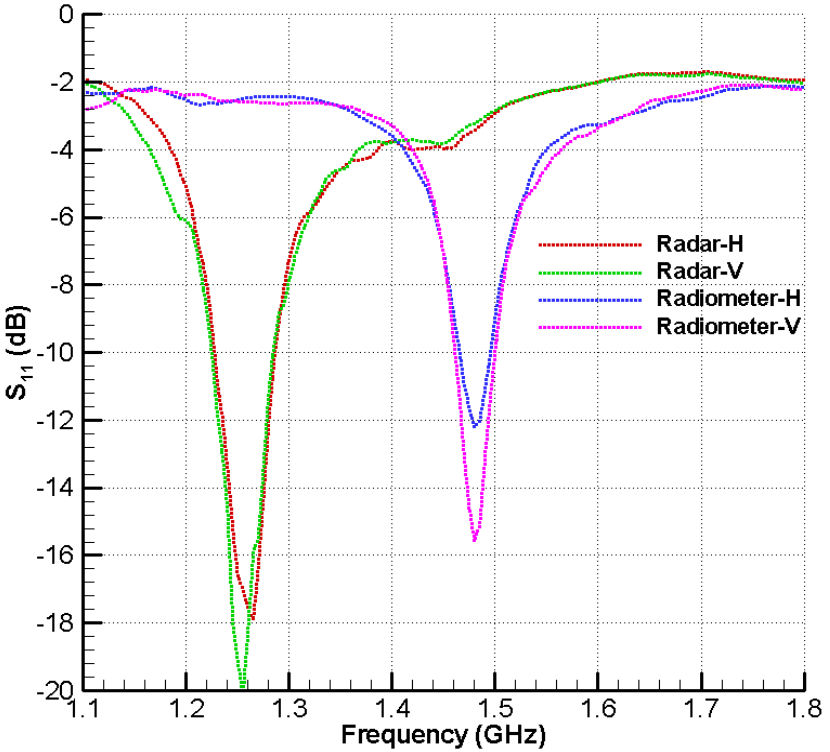
Design phase 2







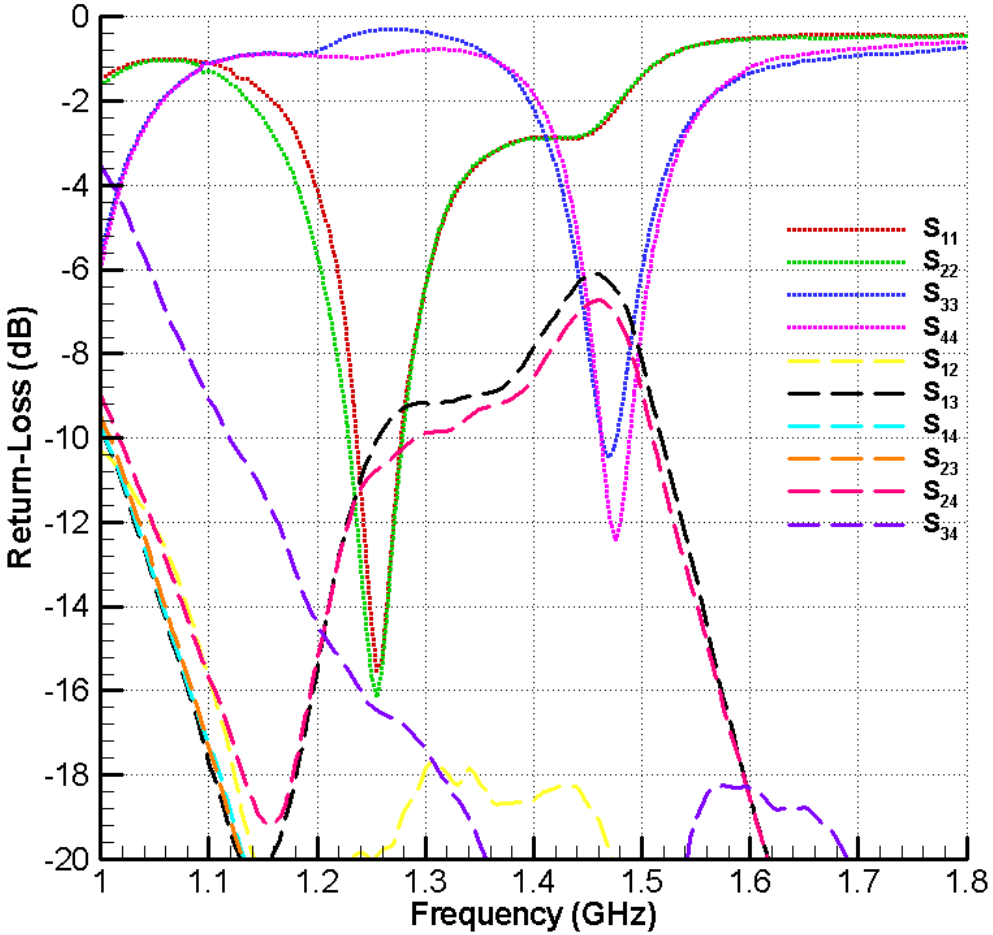
## Measured Return-Loss for Stacked Patch Element

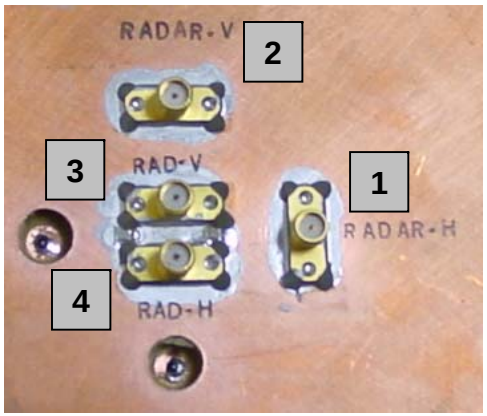



***Matched load used for the ports during measurement***

# Measured Return-loss and Isolation

Design phase 2



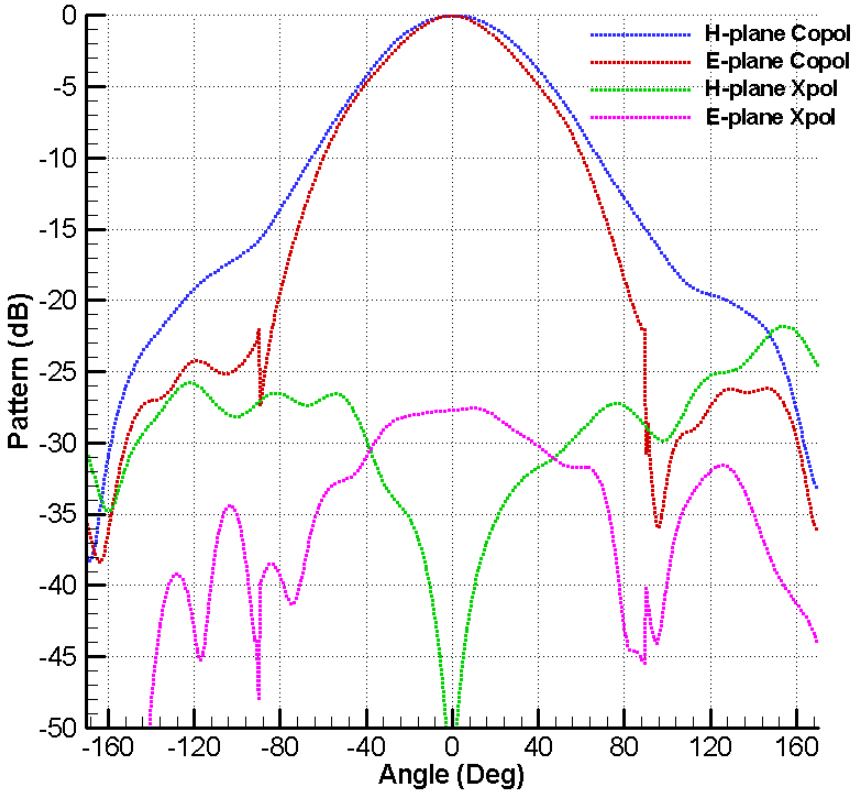

**Back-View showing the 4- ports**

## Remarks:

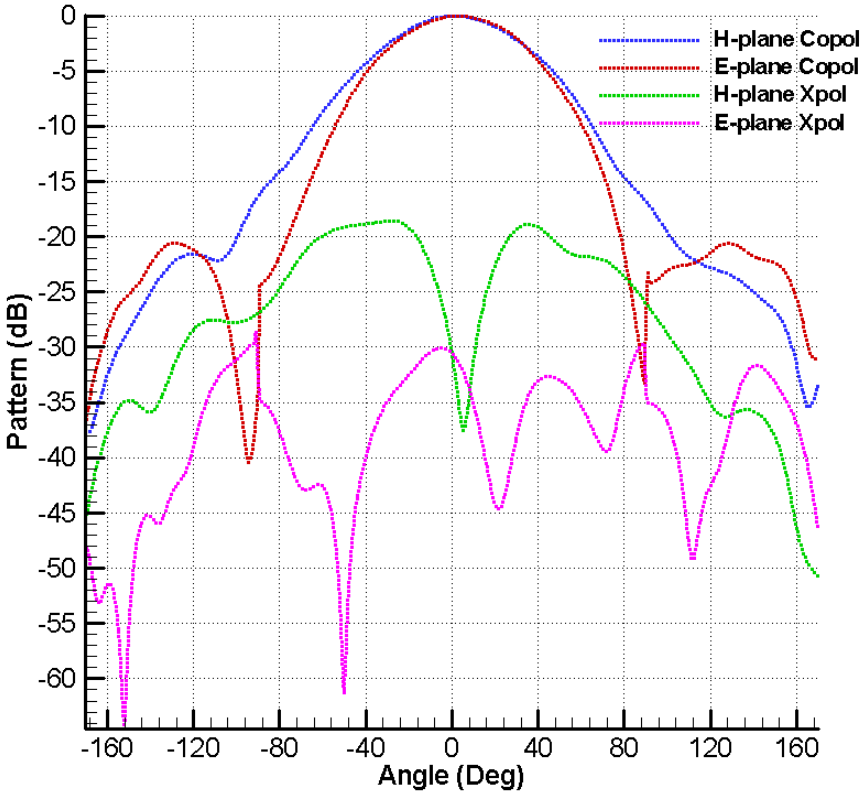
- The lower frequency of 1.26GHz was achieved. The upper frequency has a shift of 40MHz.
- It was observed that a difference in 1mm length results in a shift of ~20MHz in resonant frequency
- The mutual-coupling between the lower and upper patches was -6dB.

# Measured Radiation Pattern

Design phase 2




Radar-H port (Lower Patch)

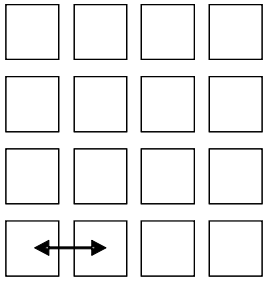



Radiometer-H port (Upper Patch)

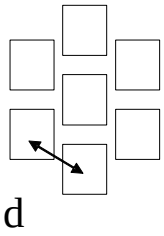
# *Array Optimization*

# Schematic of the Various Planar Array Configurations

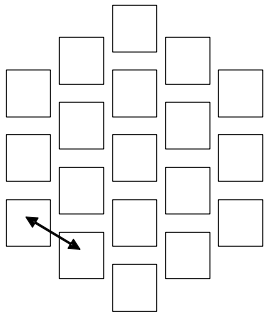
16-element



7-element




19-element

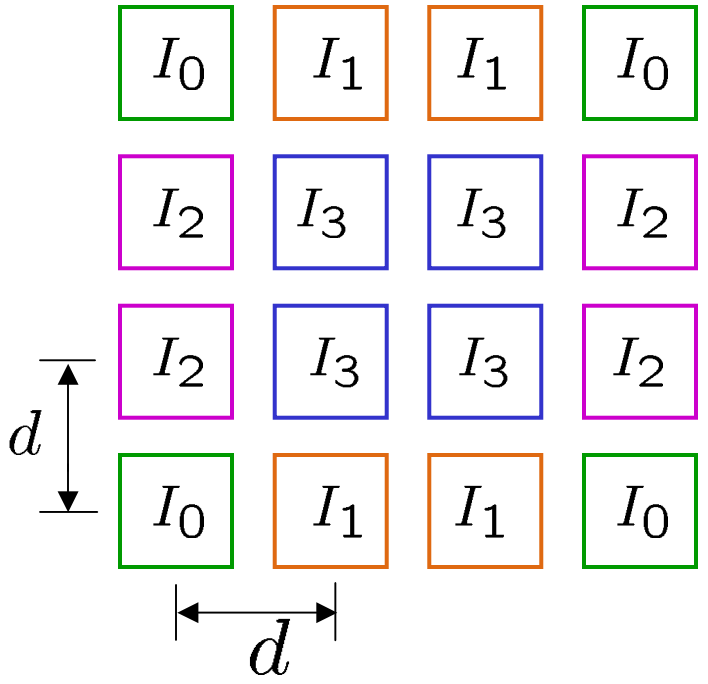


- 7-element array gives similar performance to a horn antenna as feed for the reflector.
- 16-element array provides smaller beamdwidth, easier more ground testing and aircraft platform applications
- 16- element array topology is selected for fabrication

## Array Feed Optimization

- **Optimization parameters:**
  - *Element spacing, 0.6 to 1.0 wavelengths*
  - *Element excitation, 0 to 1.0 amps.*
- **Fitness Factors**
  - *Beam efficiency*

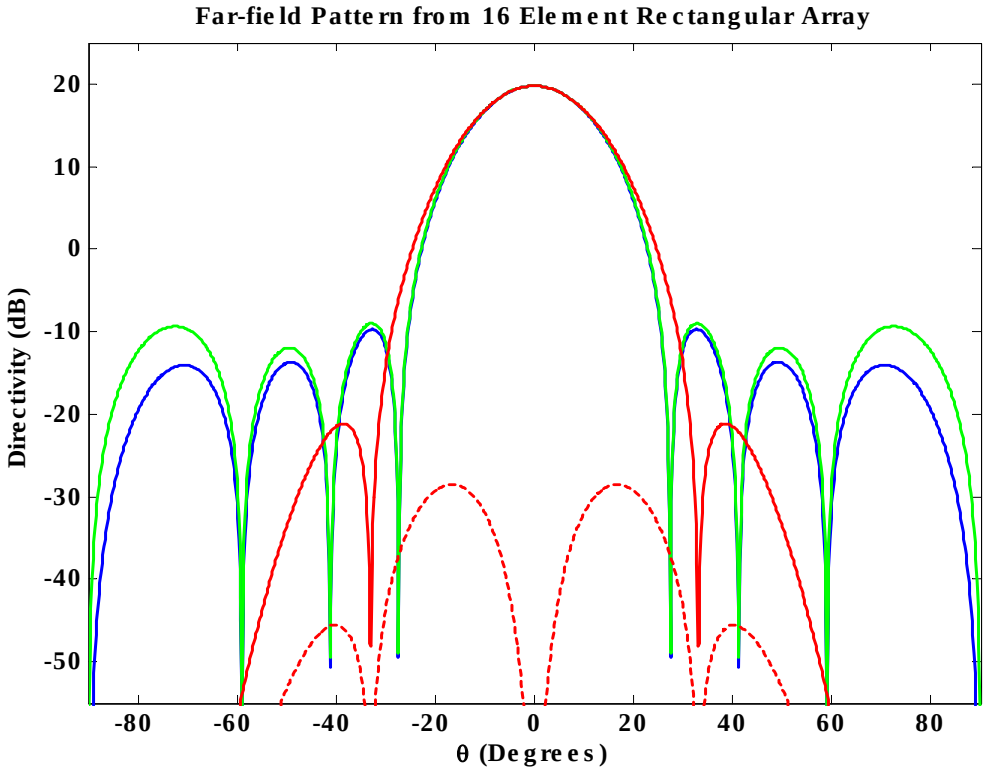
$$\vec{x} = \{d, I_0, I_1, I_2, I_3\}$$



# Optimized Array

Numbers are dB down from center elements.


$$d = 0.76\lambda_{1.41GHz}$$




**Optimized Pattern:**

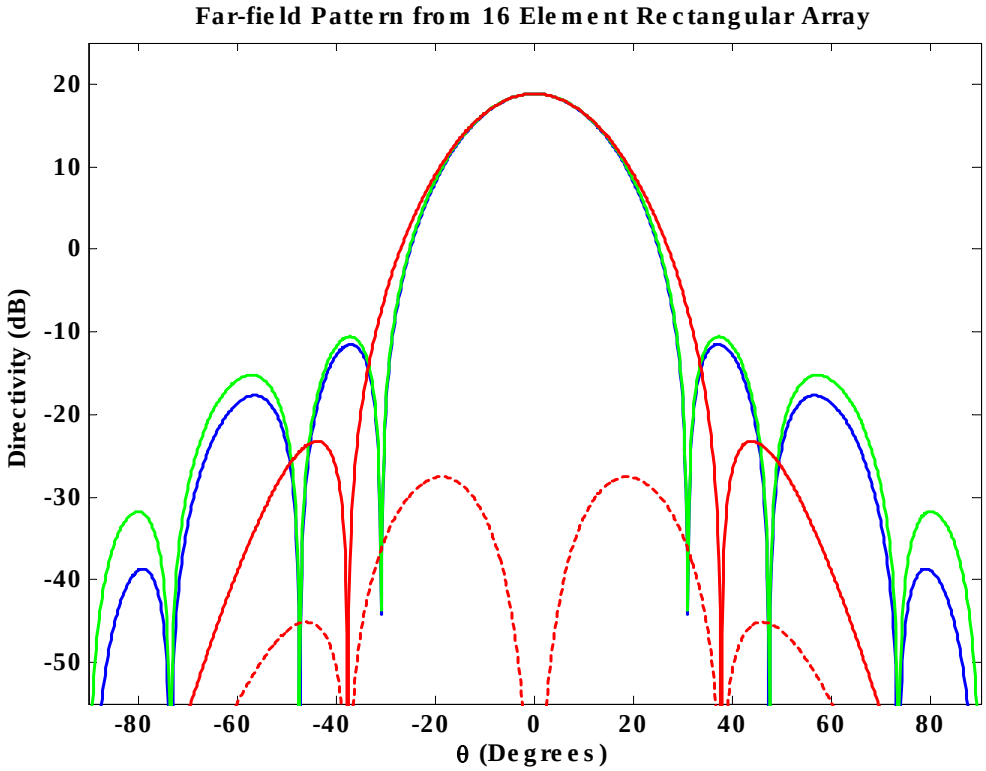
Freq. = 1.41 GHz
Boresite gain = 19.98 dB
Beam efficiency = 99.2%
HPBW Eplane = 19.8 deg.
HPBW Hplane = 20.2 deg

# 1.26 GHz Operation

Numbers are dB down from center elements.


$$d = 0.76\lambda_{1.41GHz}$$

**Same feed network as for 1.41 GHz.**




**Optimized Pattern:**

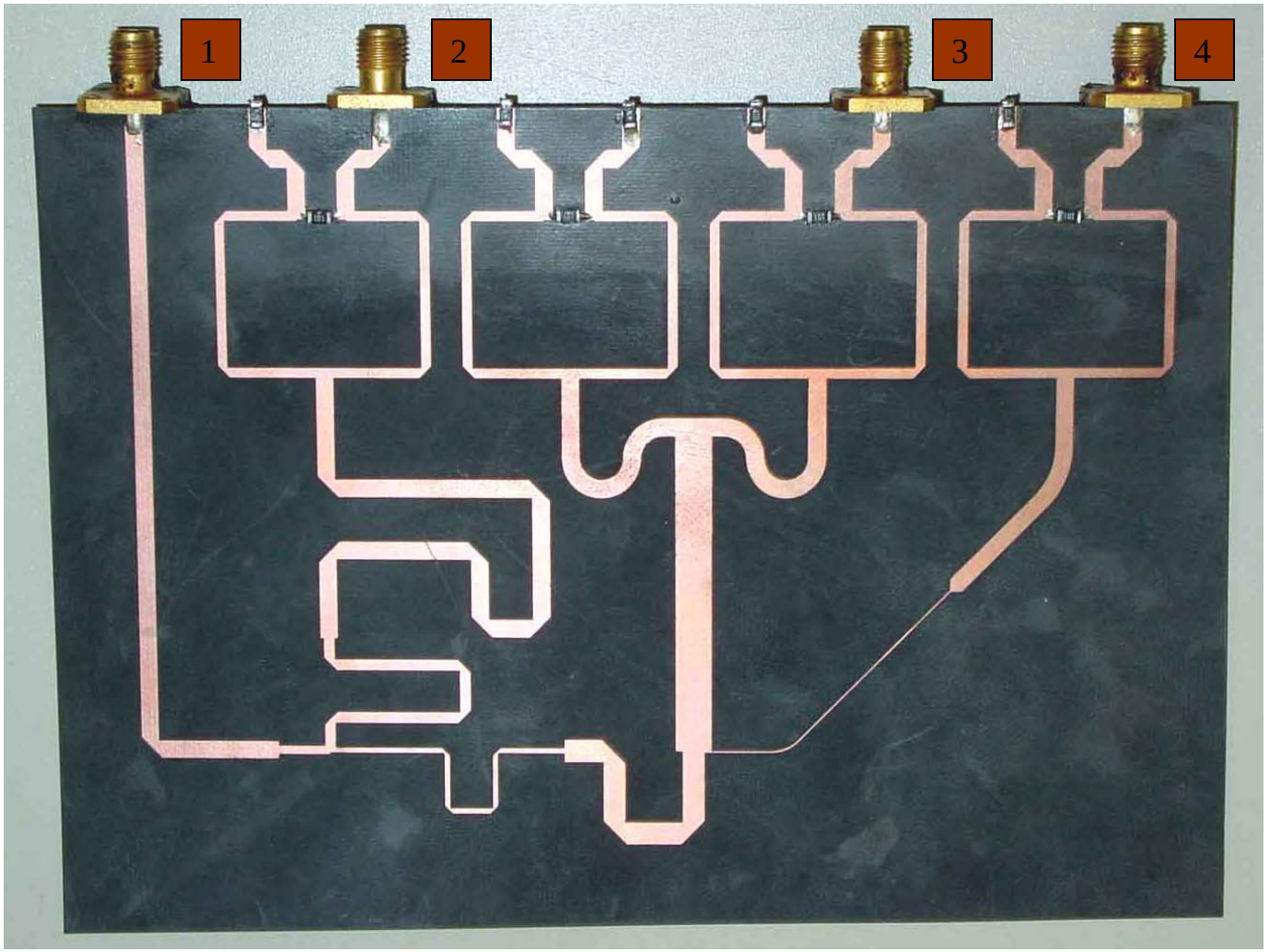
Freq. = 1.26 GHz

Boresite gain = 18.83 dB

HPBW = 22.4 degrees

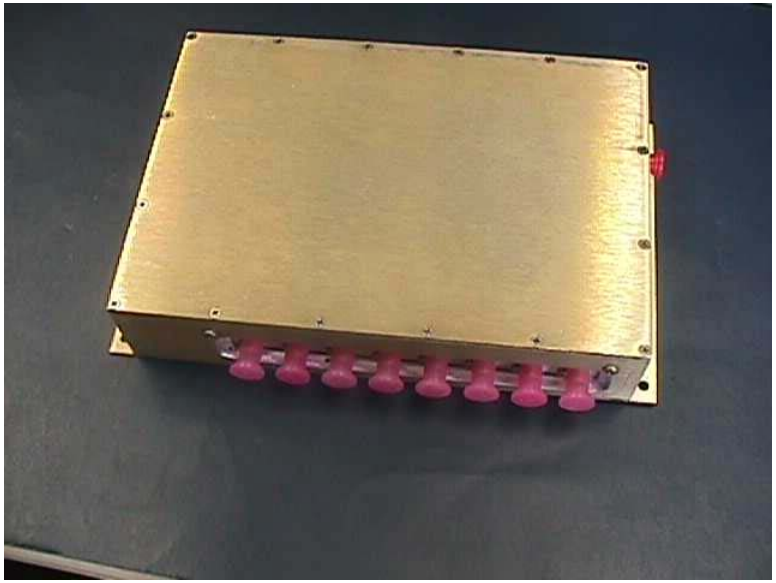
# *Feed Network Design and Prototype*

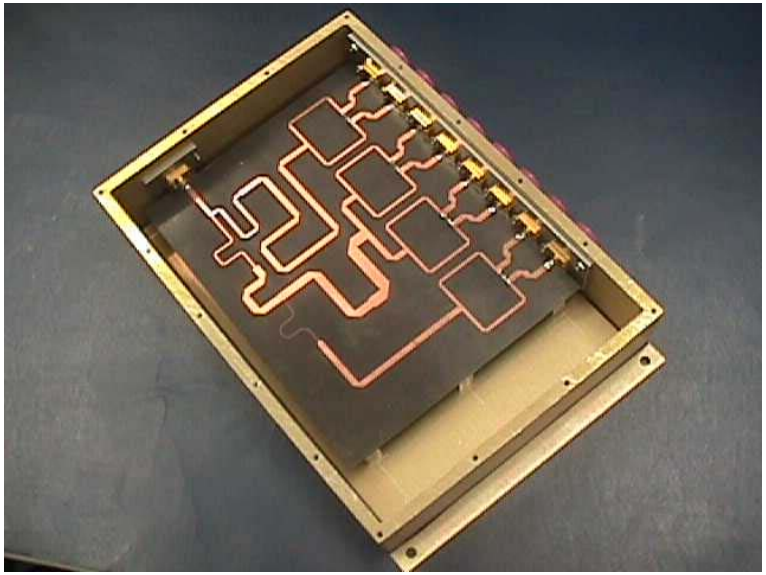
# Photograph of the 1:8 Power Splitter



## Low loss , 1:8 Power Divider, Boxed

# Box Has Negligible Impact on Insertion Loss





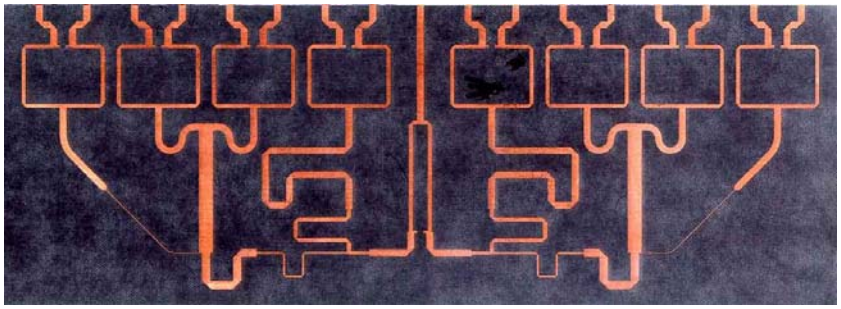
Box size (7” x 5” x 1.5”)

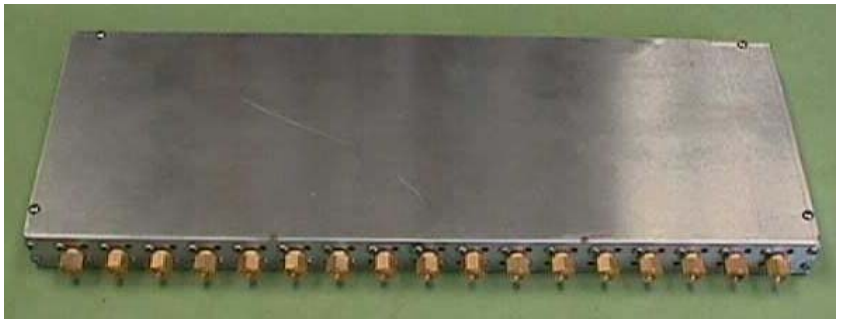
## Insertion Loss (dB)

| | Port #1 | Port #2 | Port #3 | Port #4 | Port #5 | Port #6 | Port #7 | Port #8 |
|---|---|---|---|---|---|---|---|---|
| Boxed | -5.21 | -5.06 | -11.04 | -11.15 | -11.21 | -11.26 | -19.67 | -19.27 |
| Un Boxed | -5.11 | NA | -11.04 | NA | NA | NA | -19.67 | NA |
| Difference | 0.1 | - | 0.0 | - | - | - | 0.0 | |

Boxed power divider -Measured 2/24/04 - Input 1413 Mhz @ 0.0 dBm

# ACT Low loss , 1:16 Power Divider





Measured Insertion Loss: ~0.2 dB

| Frequency (MHz) | Port 1 | Port 2 | Port 3 | Port 4 | Port 5 | Port 6 | Port 7 | Port 8 | Port 9 | Port 10 | Port 11 | Port 12 | Port 13 | Port 14 | Port 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1260 | -21.21 | -21.26 | -14.28 | -14.29 | -14.13 | -14.19 | -8.11 | -8.09 | -8.11 | -8.12 | -14.04 | -14.02 | -14.12 | -14.05 | -21.25 |
| 1413 | -21.78 | -21.67 | -14.59 | -14.61 | -14.47 | -14.55 | -8 | -7.99 | -8.01 | -8 | -14.42 | -14.35 | -14.59 | -14.52 | -21.72 |

# Summary

- Array design optimization completed
- 1:8 power divider design, fabrication and testing completed
  - Insertion loss measured to be about 0.2-0.3 dB, meeting expected requirements
  - Enclosure box has no impact on performance
- Prototype 1:16 power divider design and fabrication completed
- Array layout concept completed
- Evaluate alternate element design for frequency response

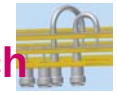
# Next Phase Plan

- Trades and downselect of the stacked patch designs
- Fabricate array elements
- Fabricate the antenna frame and coaxial cables
- Array assembly integration and test (stacked-patch elements, feed network, coaxial cables and frame)
- Perform antenna pattern measurements

# ACT Planar Antenna

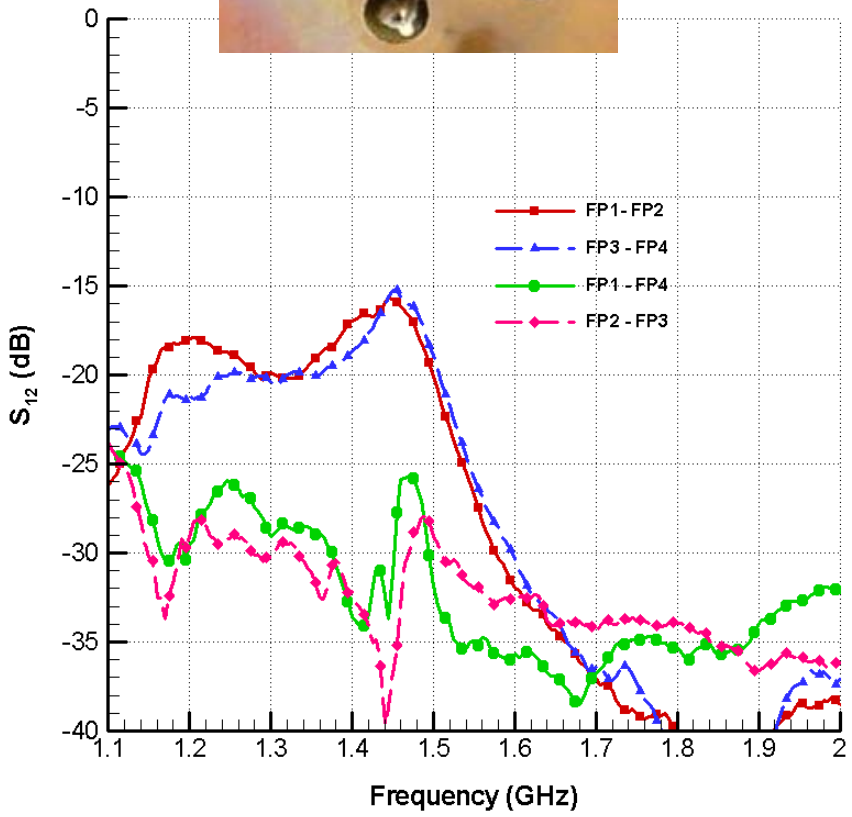
## Backup

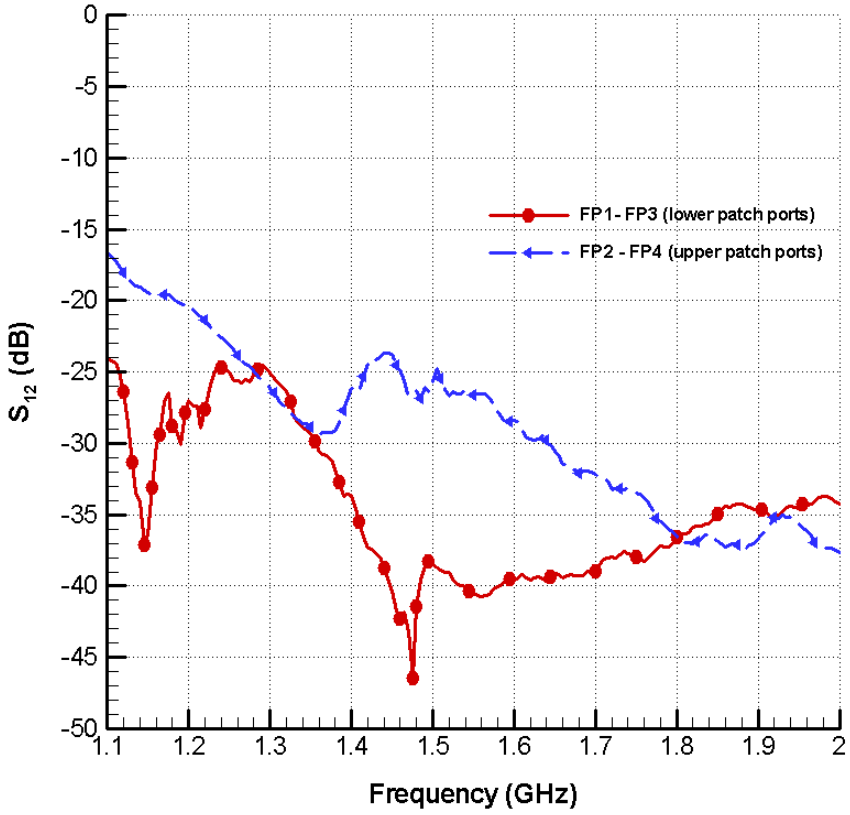
# Isolation Measurement Results of Dual-Frequency Dual-polarized Microstrip Patch



**Design phase 1**

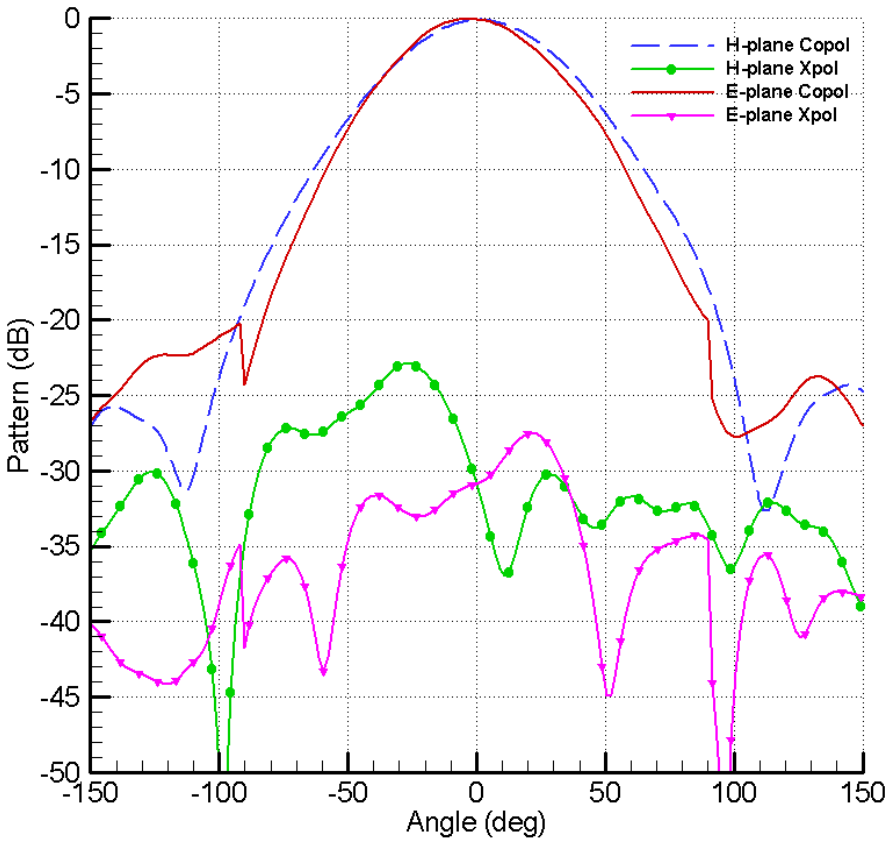

FP1: V-port (lower patch)
FP3: H-port (lower patch)
FP2: V-port (upper patch)
FP4: H-port (upper patch)



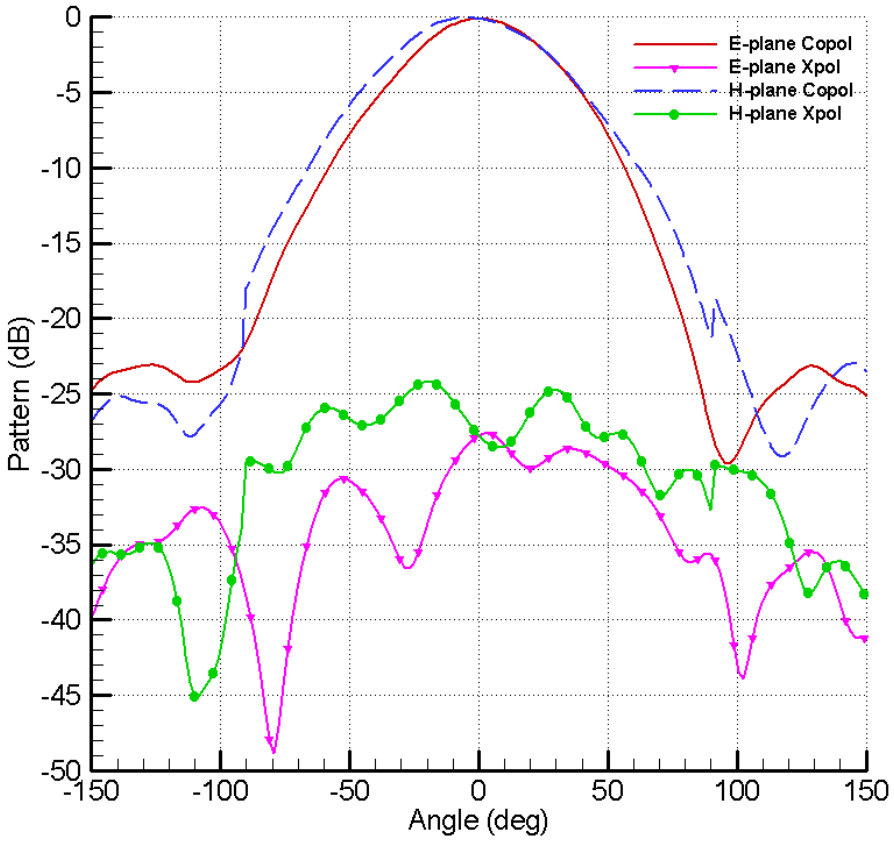



# Measured Radiation Pattern for Dual-Frequency Dual-Polarized Stacked Microstrip Patch

**Design phase 1**



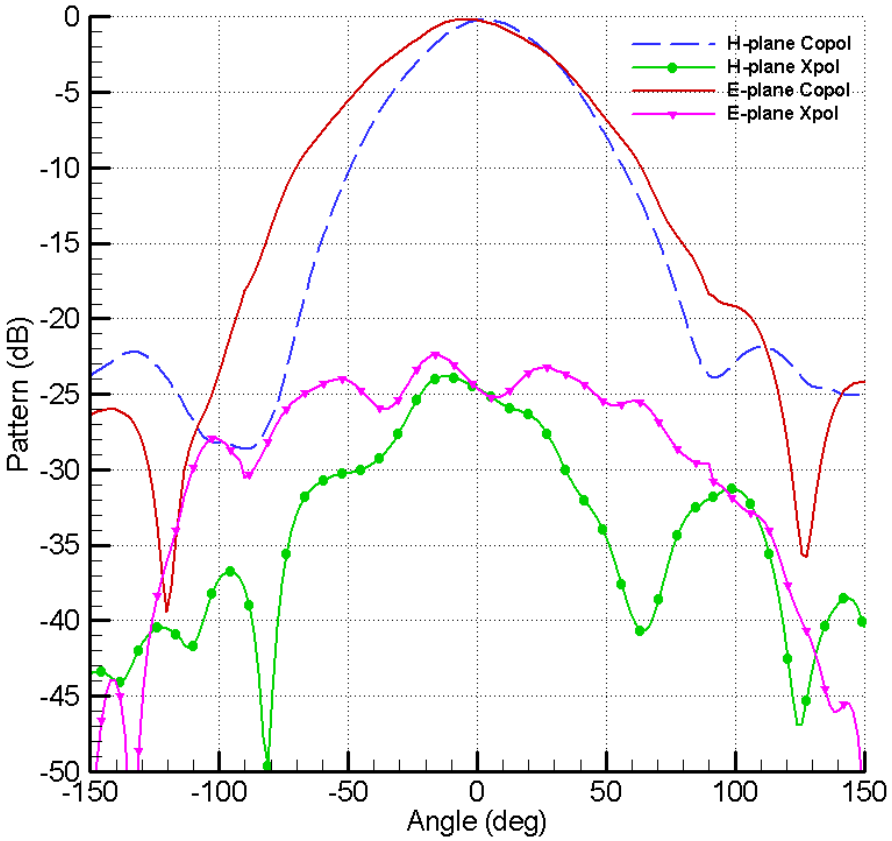

Radiation Pattern for Lower patch
(V-port: FP1)



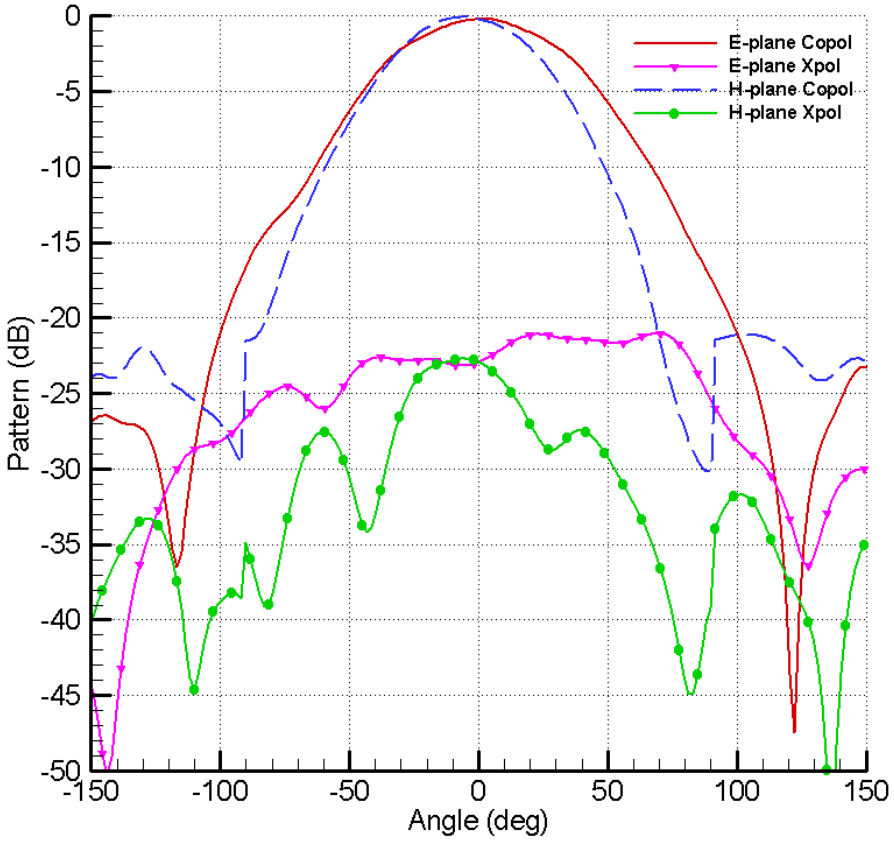

Radiation Pattern for Lower patch
(H-port: FP3)

# Measured Radiation Pattern for Dual-Frequency Dual-Polarized Stacked Microstrip Patch

**Design phase 1**




Radiation Pattern for Upper patch
(V-port: FP4)



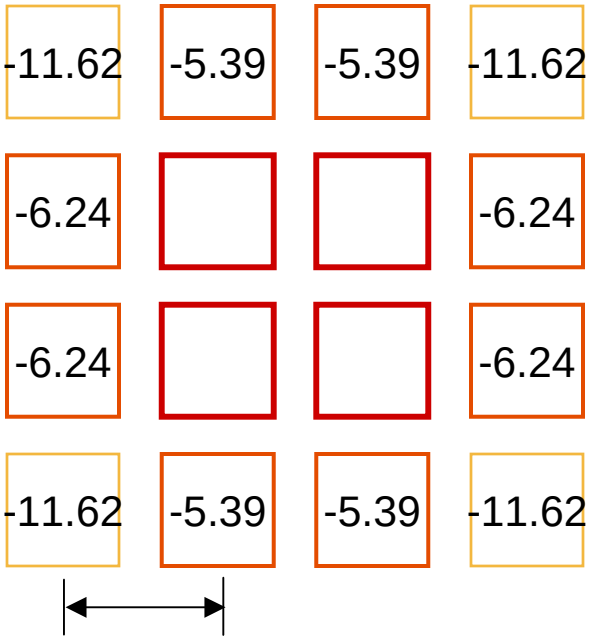

Radiation Pattern for Upper patch
(H-port: FP2)

# Fitness Calculation

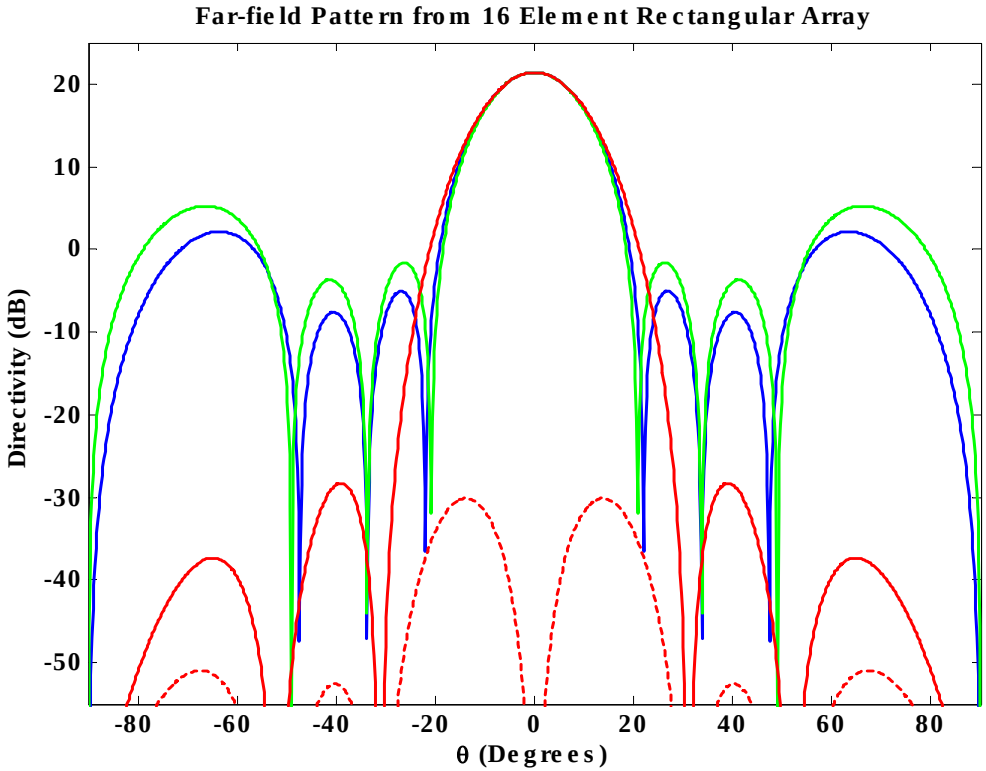
| | |
|---|---|
| (1) Position vector from PSO: | $\vec{x} = \{d, I_0, I_1, I_2, I_3\}$ |
| (2) Reformat for 16 elements: | $\mathbf{I} = \{I_0, ..., I_{15}\}$<br>$\mathbf{X} = \{x_1, ..., x_{15}\}$<br>$\mathbf{Y} = \{y_1, ..., y_{15}\}$ |
| (3) Find total radiated power from DUAL: | $P_{\text{total}}$ |
| (4) Find HPBW from far-field pattern: | HPBW |
| (5) Radiated power from $0 < \theta < 1.25 \times \text{HPBW}$ | $P_{\text{beam}}$ |
| (6) Calculate fitness value: | $F = \left(100 - 100\frac{P_{\text{beam}}}{P_{\text{total}}}\right)^2$ |

# Optimization w/ Fixed Spacing

Numbers are dB down from center elements.



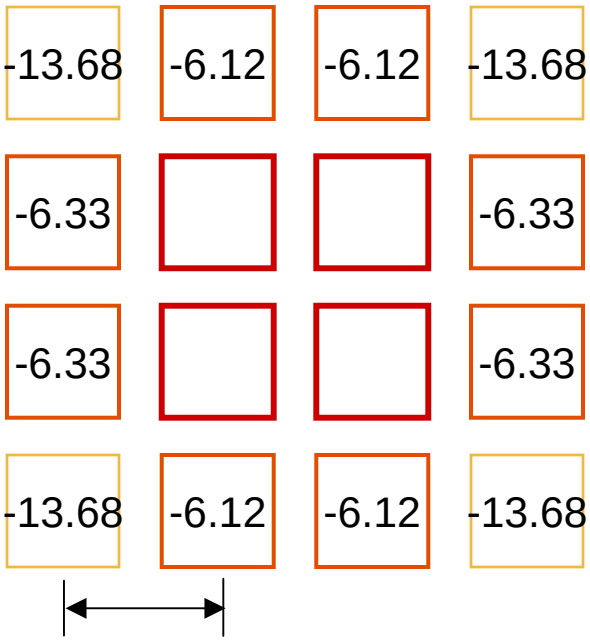

$$d = 0.9\lambda_{1.41GHz}$$



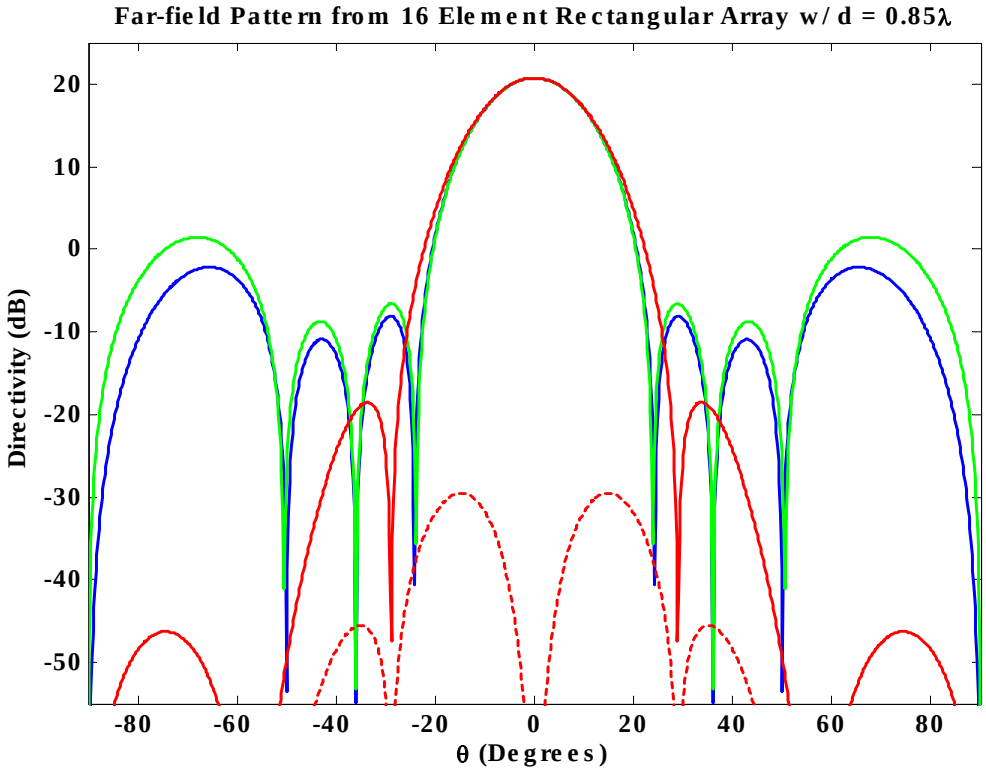

**Optimized Pattern:**

Freq. = 1.41 GHz
Boresite gain = 21.08 dB
Beam efficiency = 92.5%
HPBW Eplane = 16.8 deg.
HPBW Hplane = 16.4 deg

# Optimization w/ Fixed Spacing



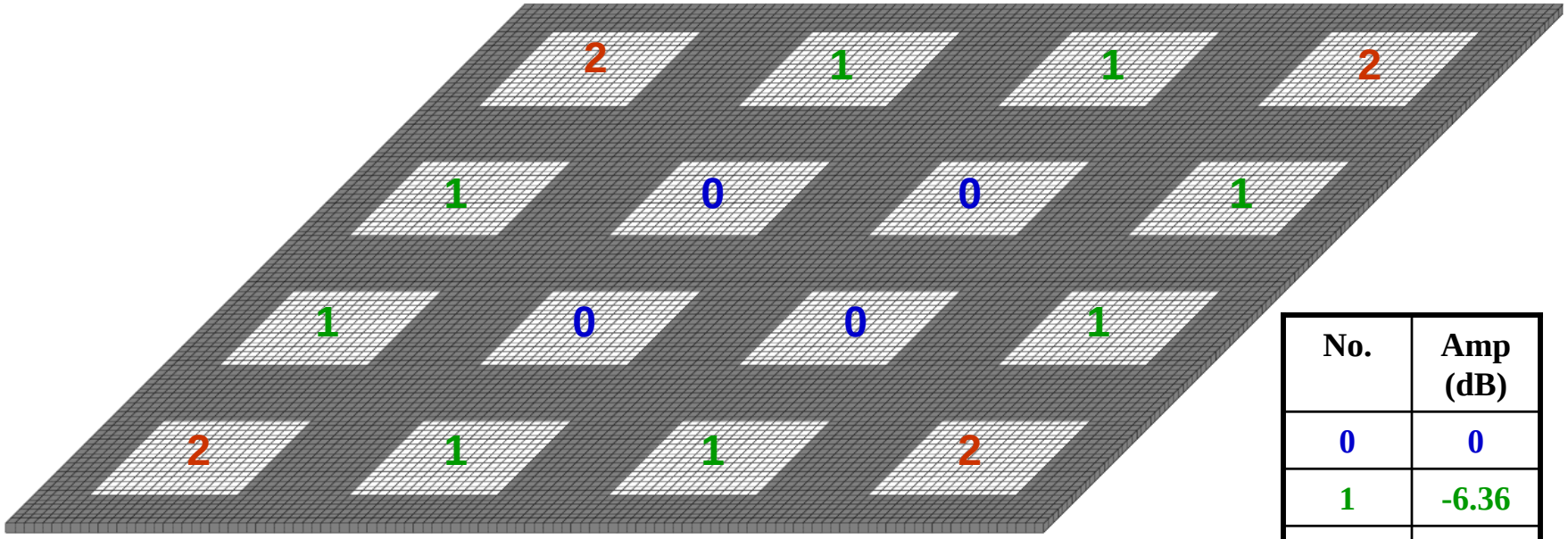

$$d = 0.85\lambda_{1.41GHz}$$




**Optimized Pattern:**

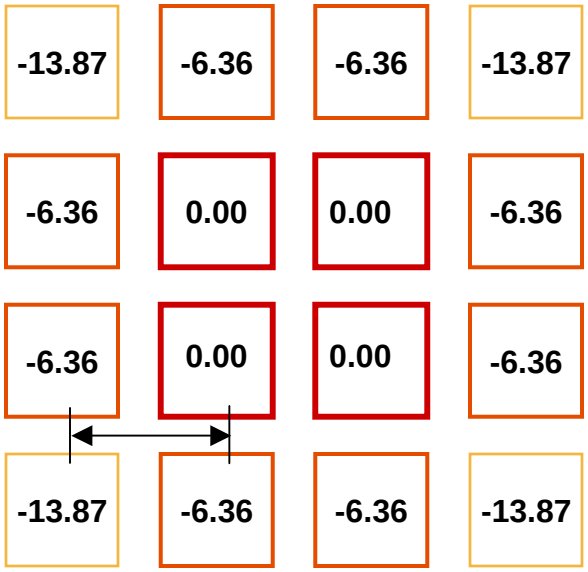
Freq. = 1.41 GHz
Boresite gain = 20.59 dB
Beam efficiency = 96.7%
HPBW Eplane = 18.0 deg.
HPBW Hplane = 18.0 deg

# 16-element array simulation with unequal amplitude excitations




Mesh generated using FDTD

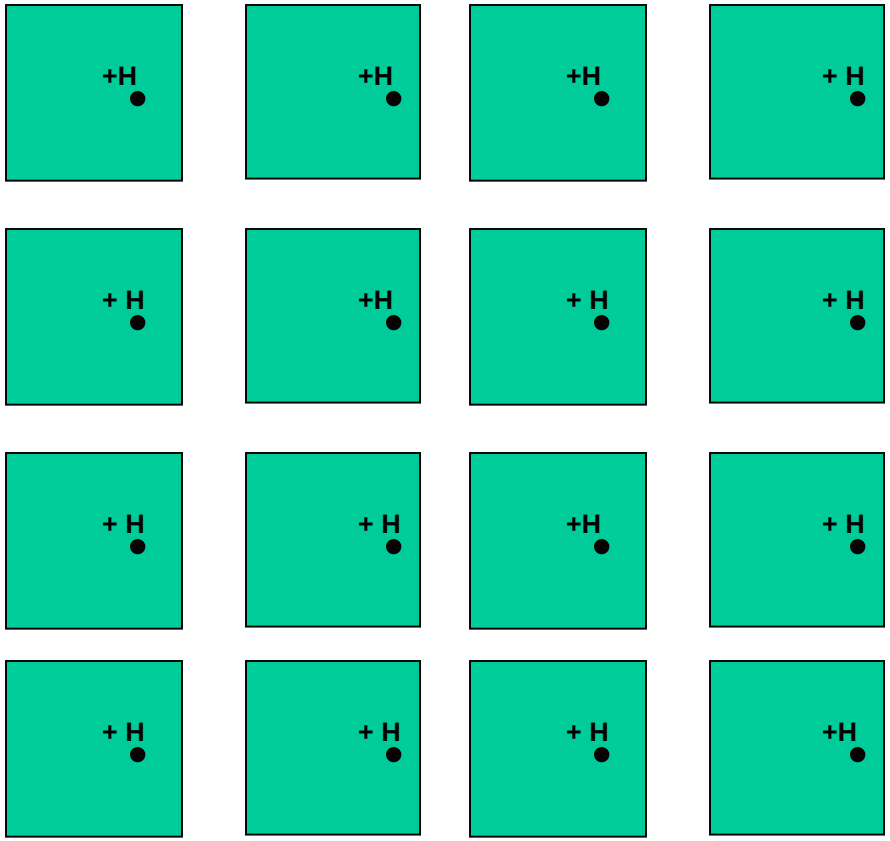
| No. | Amp (dB) |
|---|---|
| 0 | 0 |
| 1 | -6.36 |
| 2 | -13.87 |

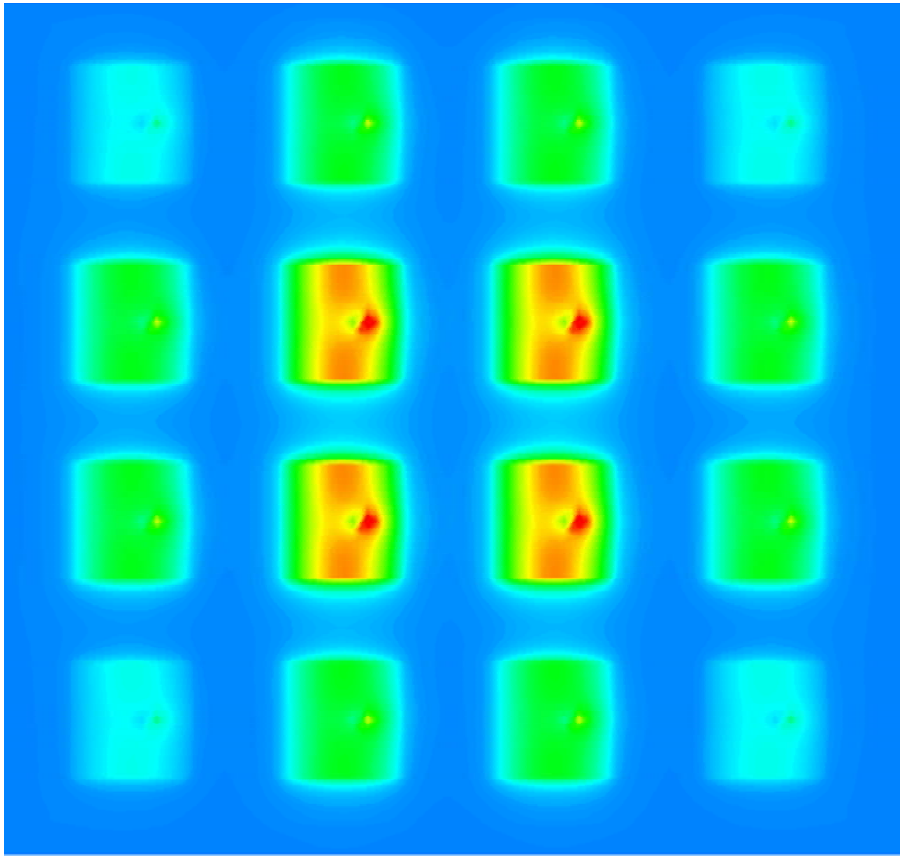



Original Size of the array

$$d = 0.76\lambda_{1.41GHz}$$

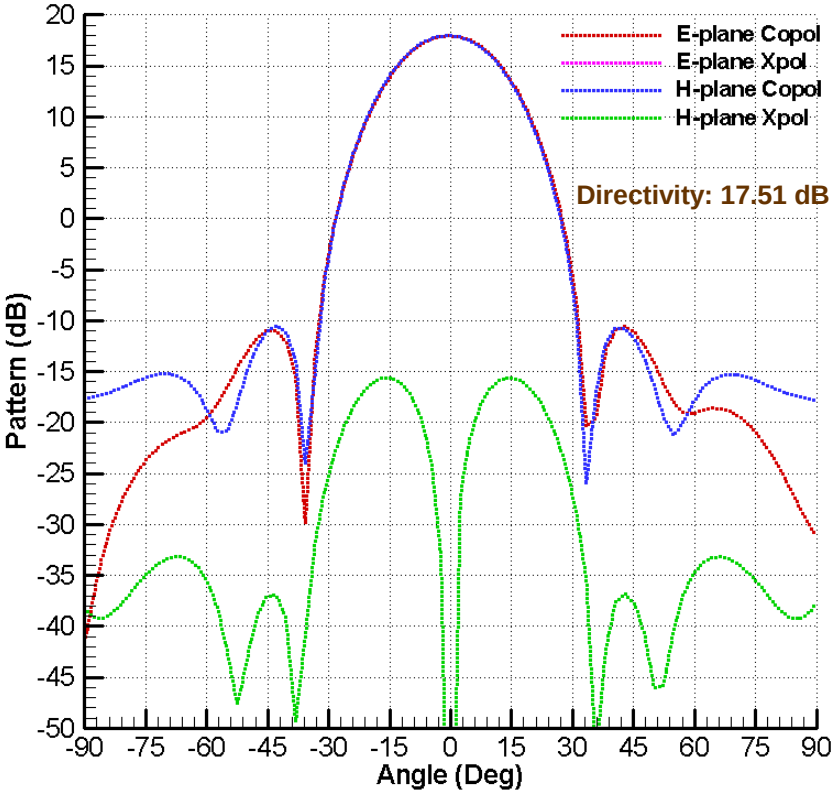
# Configuration A : Horizontal polarization



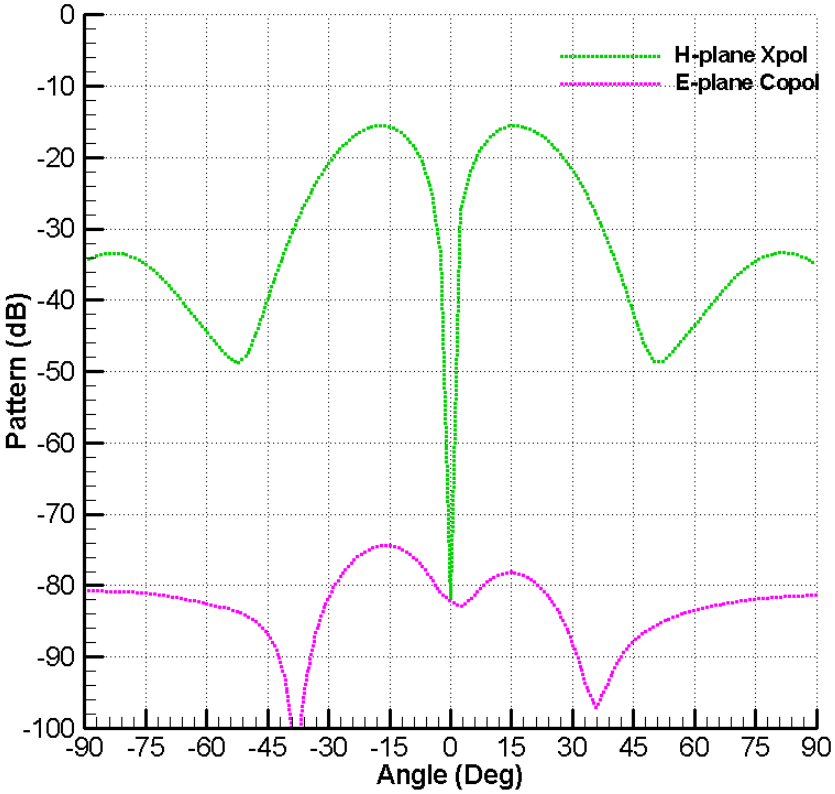



Current - distribution

# Configuration A : Horizontal polarization

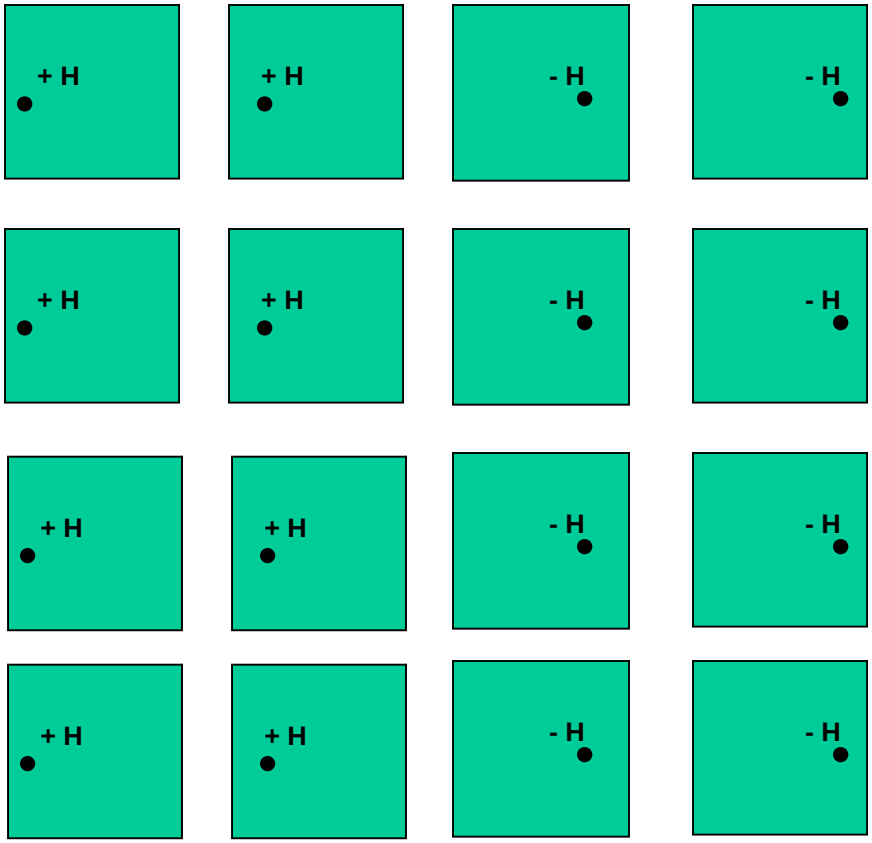


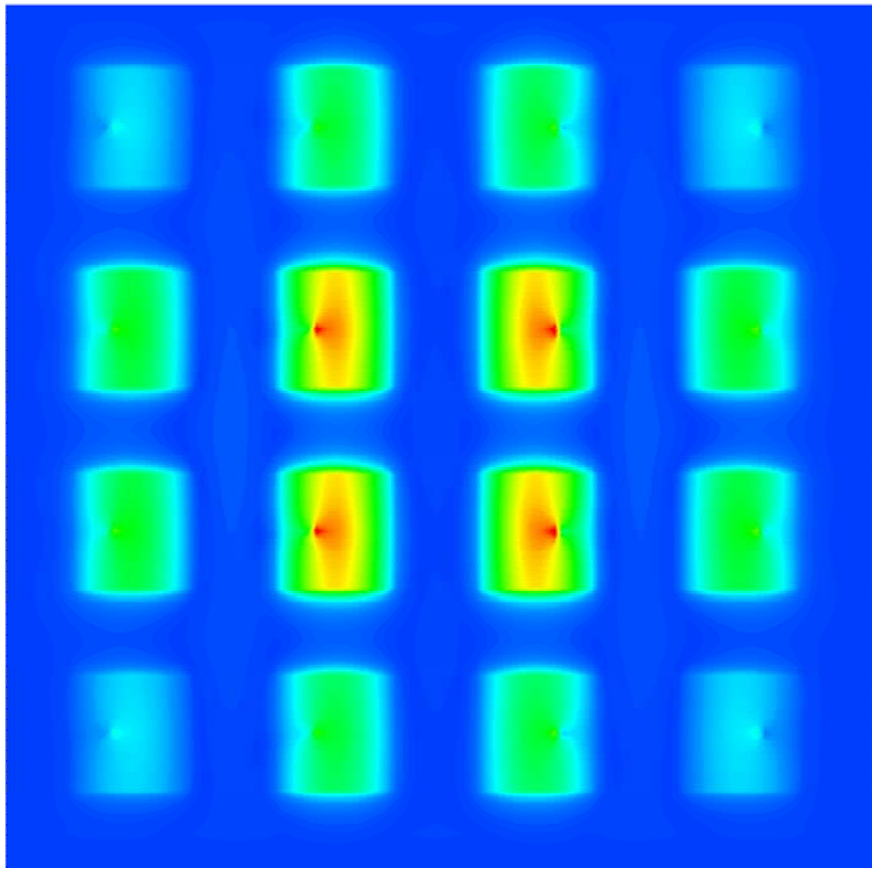

Radiation pattern (Co-pol)




Radiation pattern (X-pol)

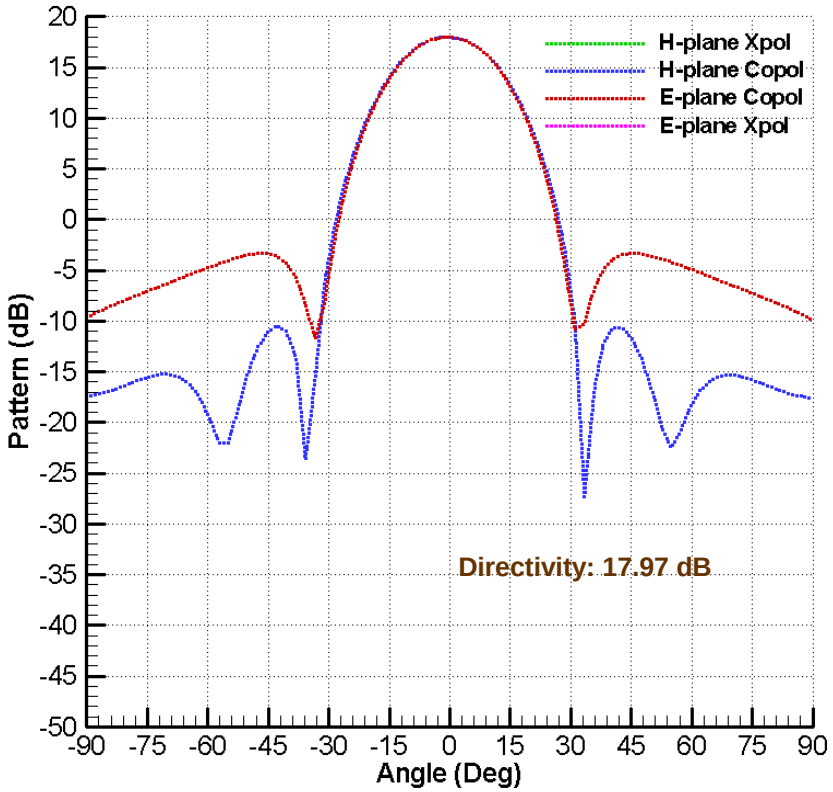
# Configuration B : Horizontal polarization



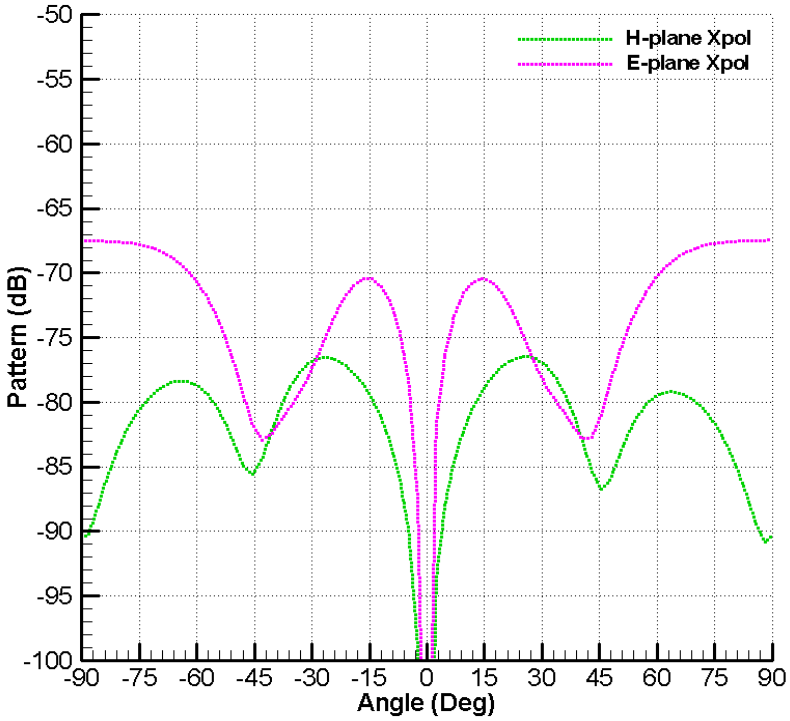



Current - distribution

# Configuration B : Horizontal polarization

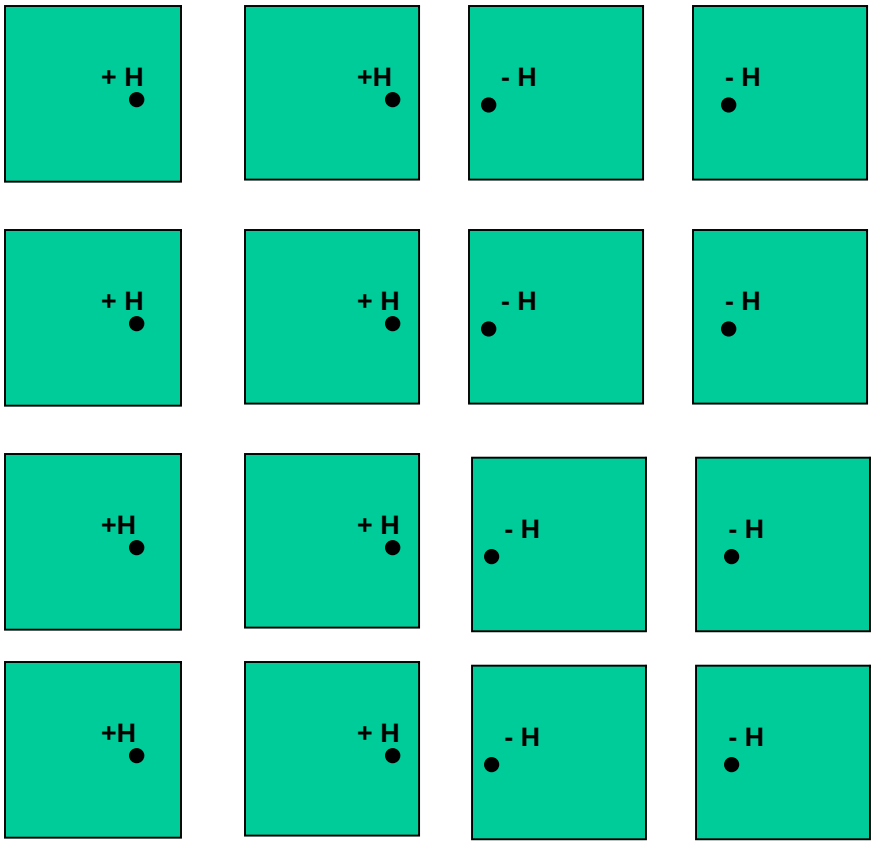


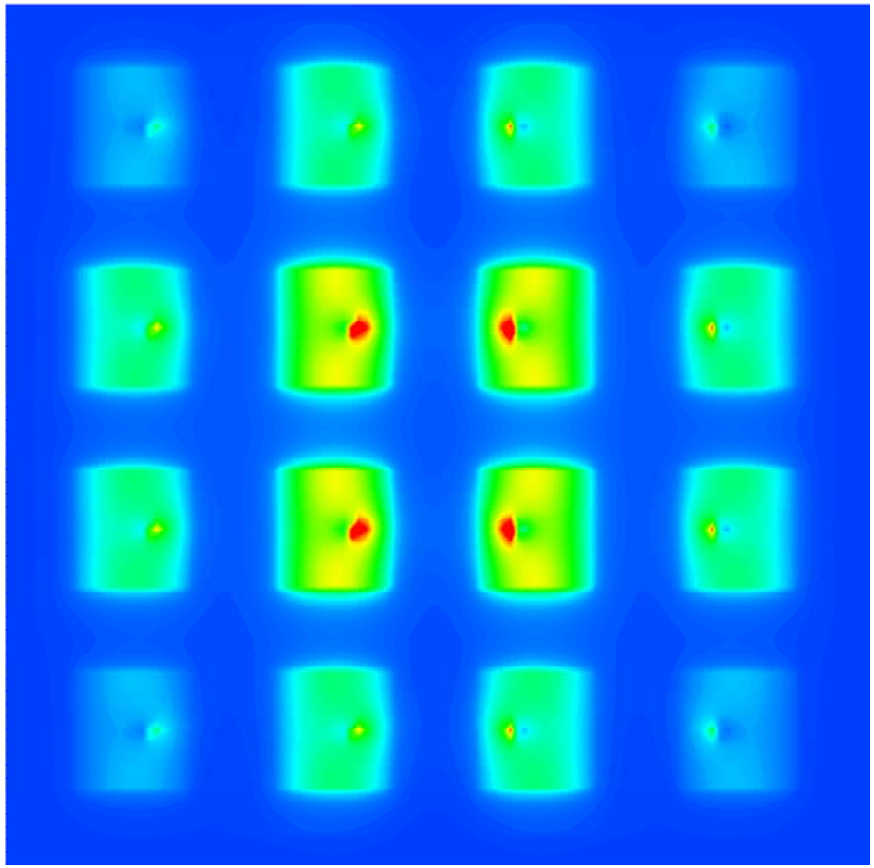

Radiation pattern (Co-pol)



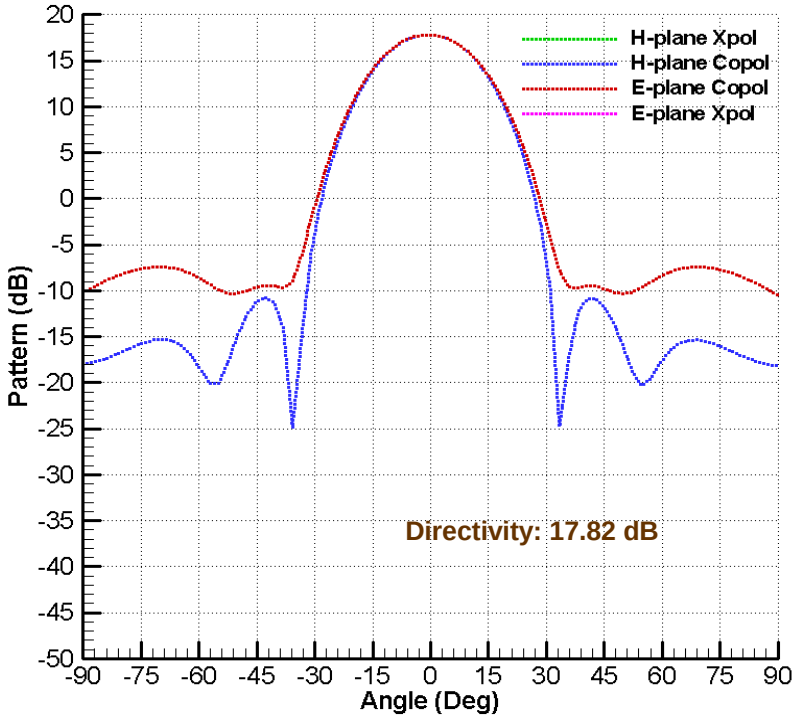

Radiation pattern (X-pol)

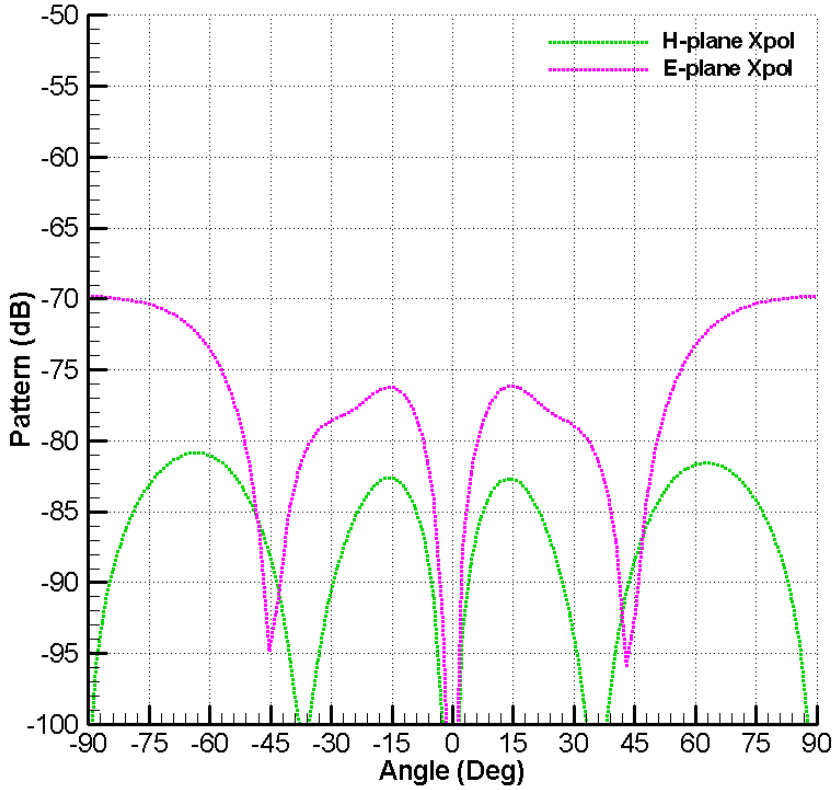
# Configuration C : Horizontal polarization



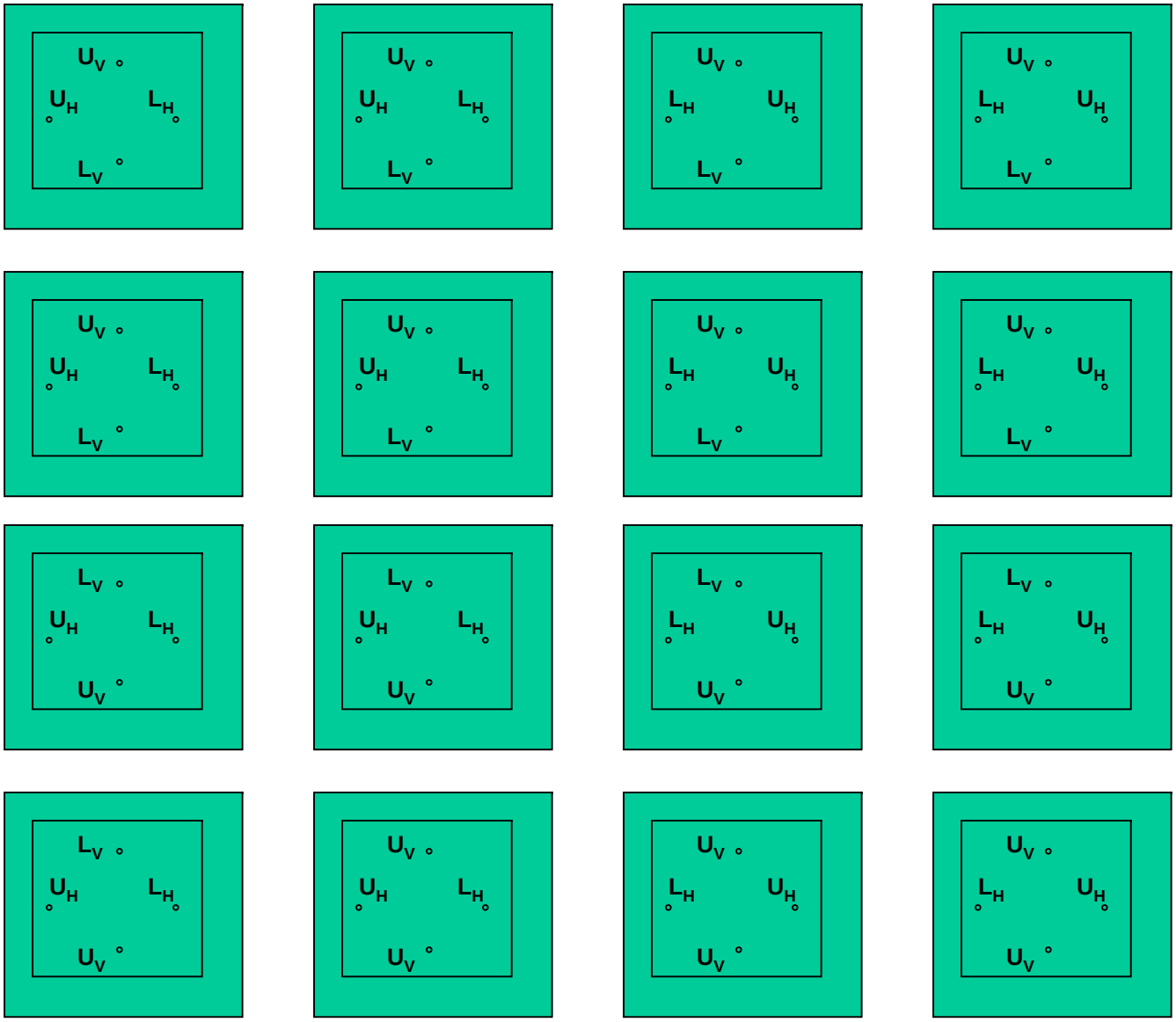



# Configuration C : Horizontal polarization



# Dual-Frequency Dual-Polarized Stacked Patch Array Configuration




$L_H$: Lower patch Horizontal Polarization

$L_V$: Lower patch Vertical Polarization

$U_H$: Upper patch Horizontal Polarization

$U_V$: Upper patch Vertical Polarization

The above configuration shows the entire sixteen element array structure with the feed locations of individual elements