ECE687
Antenna Theory and Design

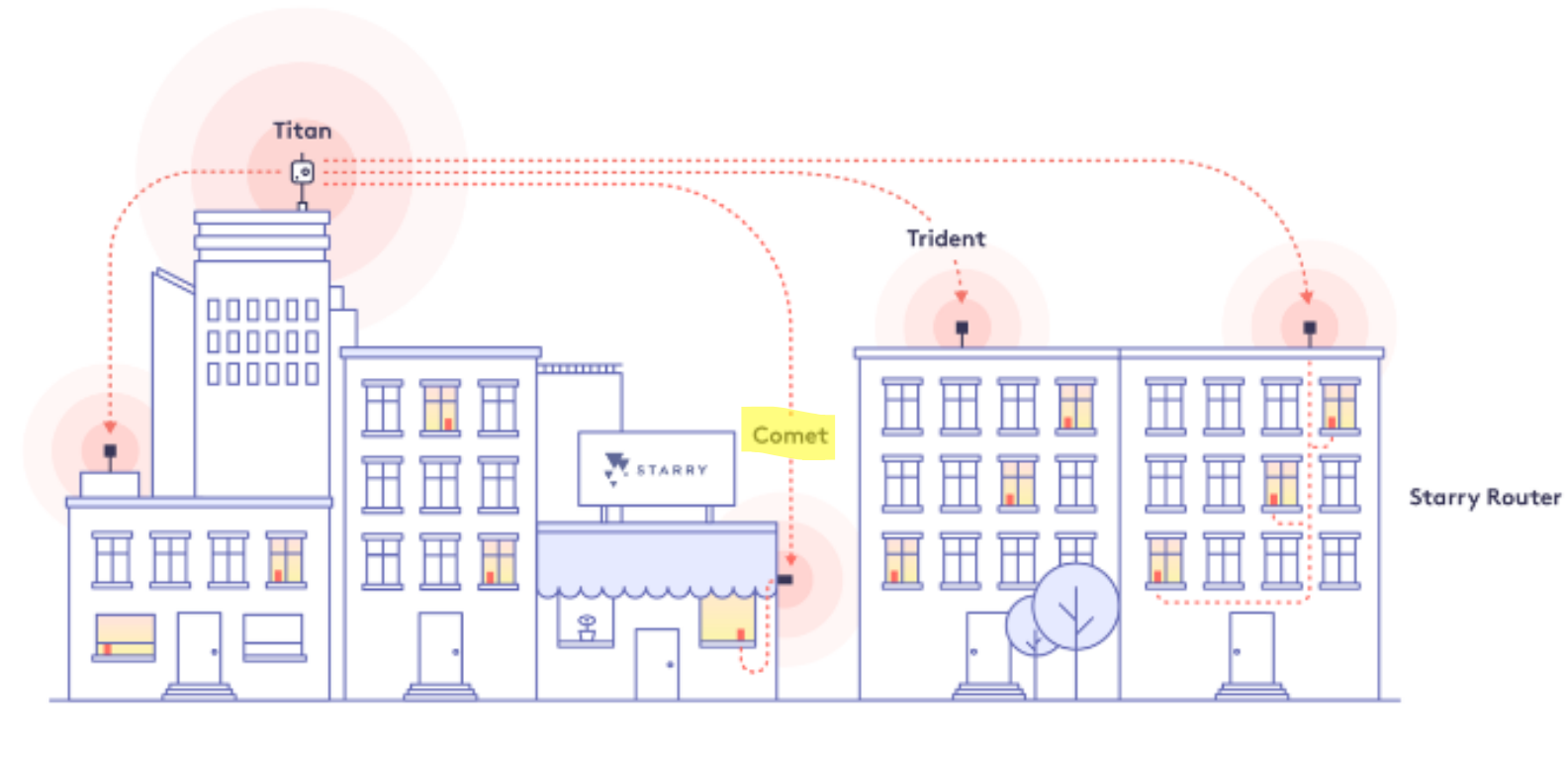
24GHZ FIXED POINT ANTENNA

Presented by Peter Adam Pawelski

University of Massachusetts Amherst
BE REVOLUTIONARY™

1. TARGET APPLICATION

Starry Inc 24GHz Fixed Point Wireless Antenna



[1]

[2]

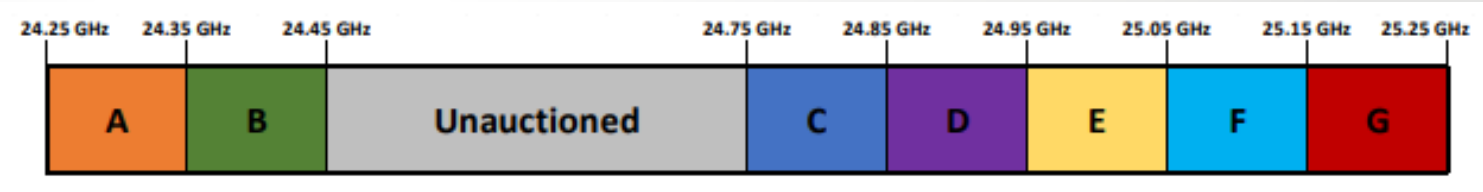
2. APPLICATION REQUIREMENTS TO ANTENNA SPECIFICATIONS

Goal of around 11-14dB directivity

Typically, between 8-20dB of gain [3]

HPBW Horizontal ~30/25deg

HPBW Vertical ~80/75deg



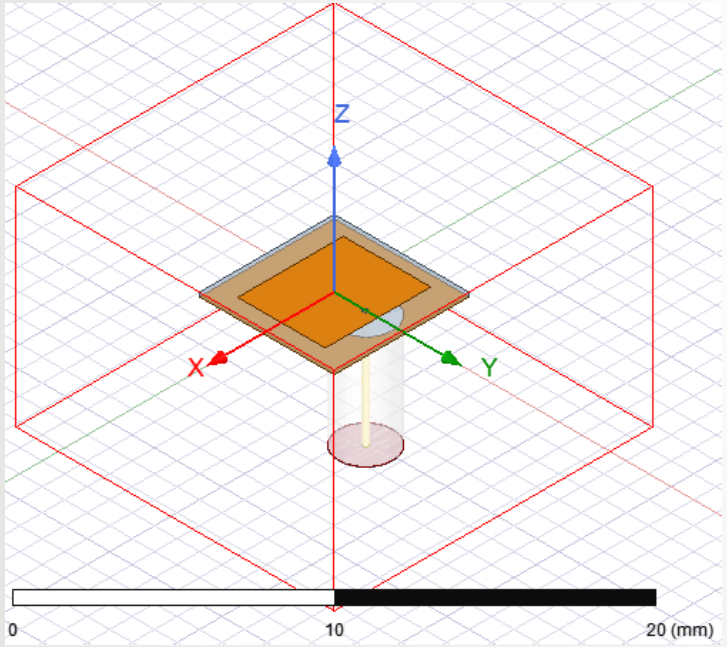
[4]

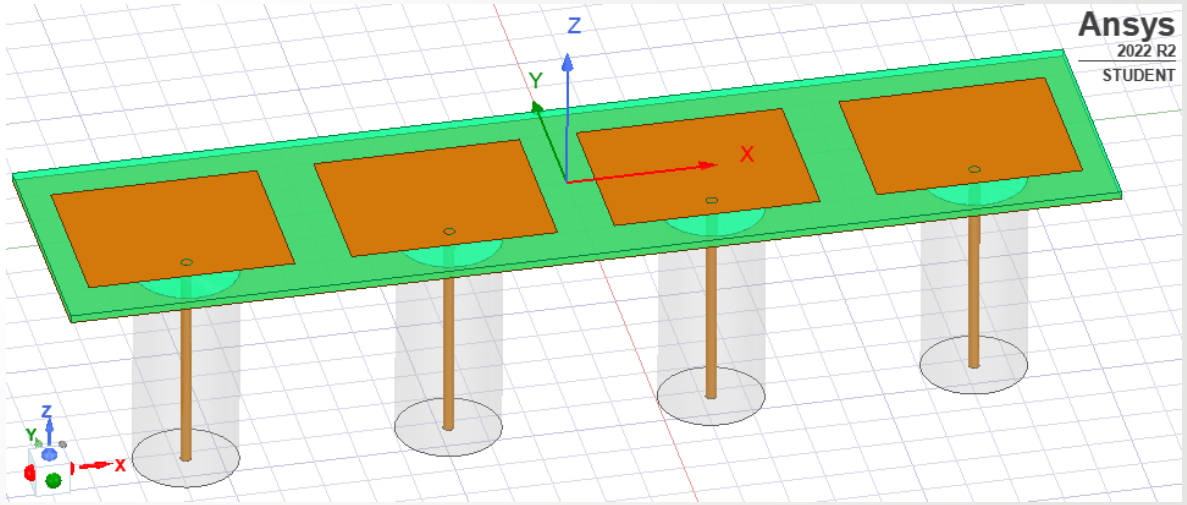
Aiming for at least 500 MHz Bandwidth

Using VSWR ≤ 2 or return loss ≤ -10dB [3]

3. CHOSEN ANTENNA TYPE

Linear Probe Fed Patch Antenna Linear Array





4. DESIGNING SIZE, SHAPE, MATERIAL, AND FEEDING DETAILS

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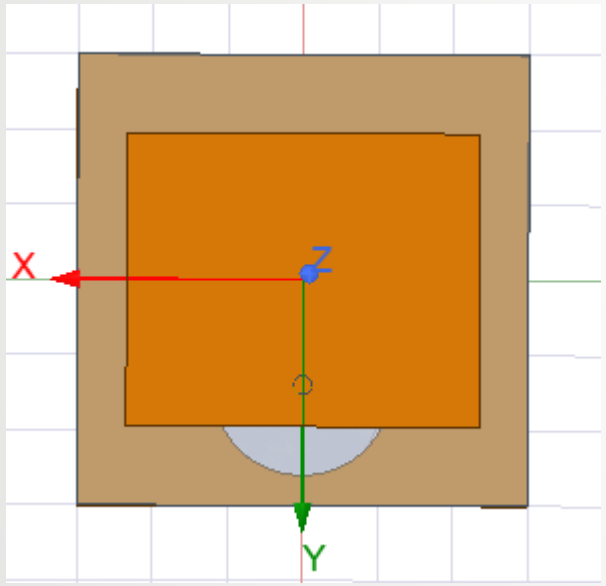
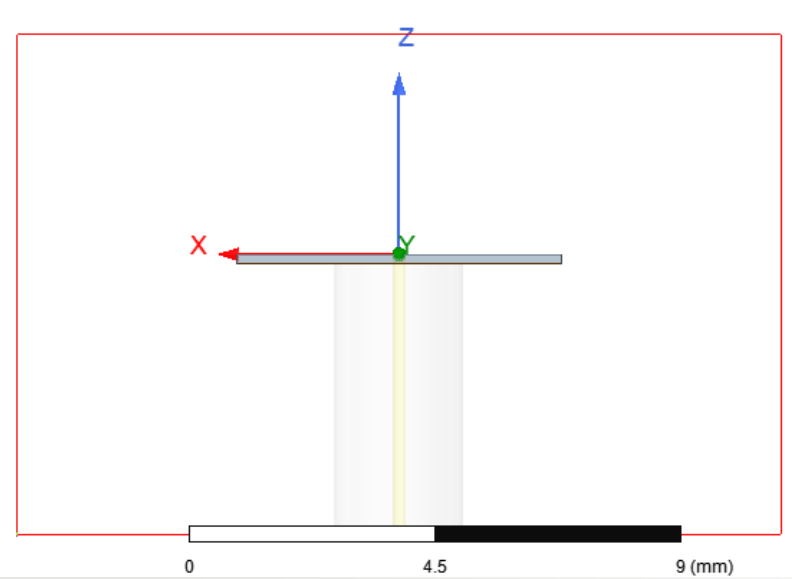
SINGLE ELEMENT PATCH DIMENSIONS

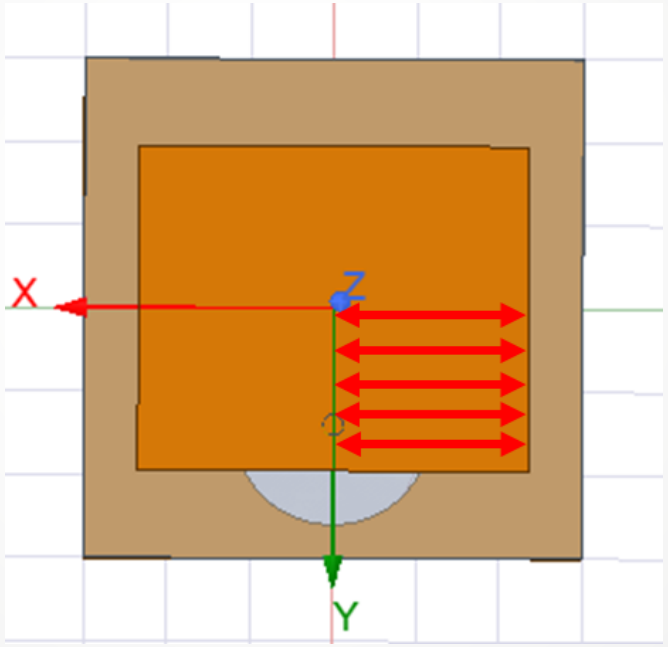


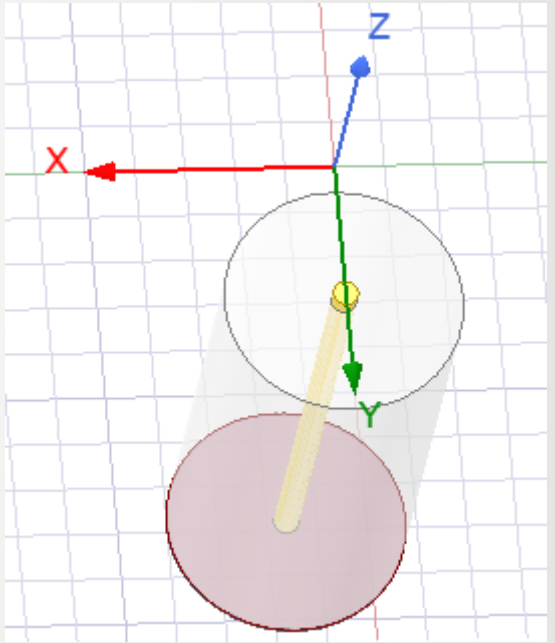
Variable	Formula
W	$\frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}}$
ε_{eff}	$\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}$
ΔL	$0.412h\frac{\left(\varepsilon_{eff}+0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{eff}-0.258\right)\left(\frac{W}{h}+0.8\right)}$
L_{eff}	$\frac{c}{2f_0\sqrt{\varepsilon_{eff}}}$
L	$L_{eff}-2\Delta L$

[6]

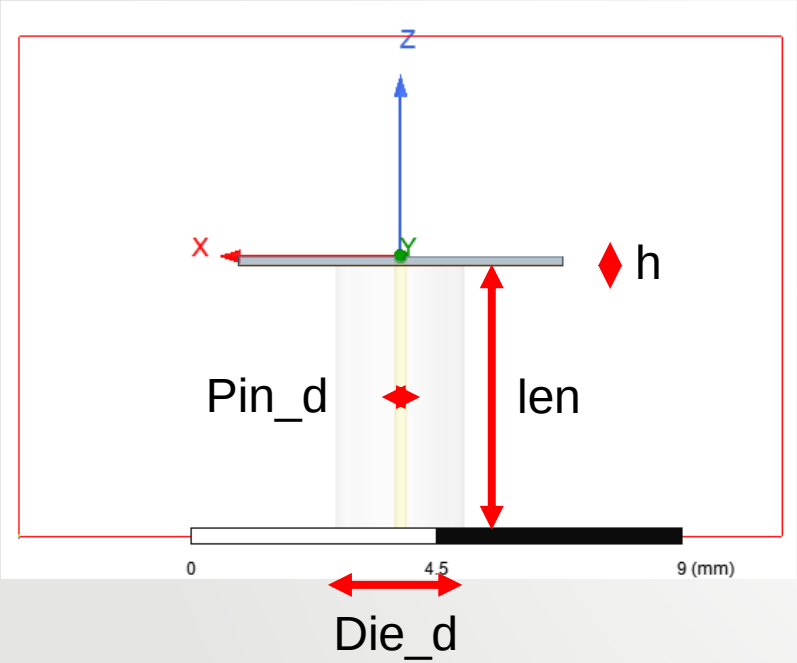
FEED DETAILS

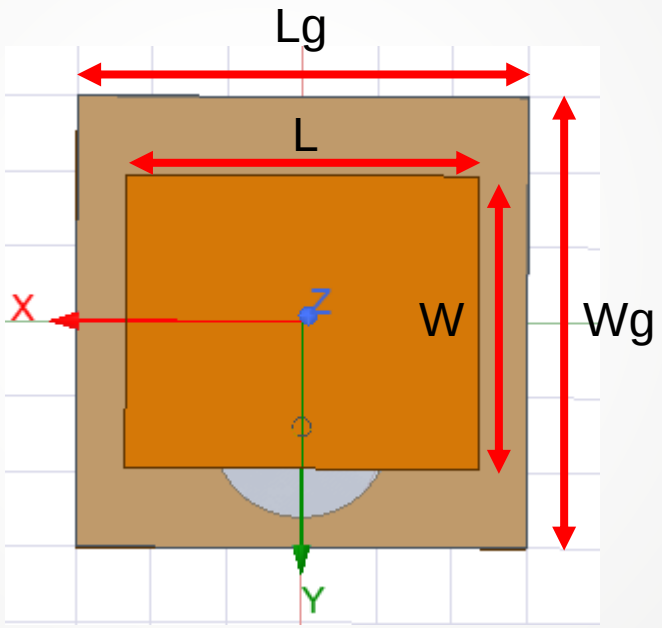






FINAL SINGLE ELEMENT





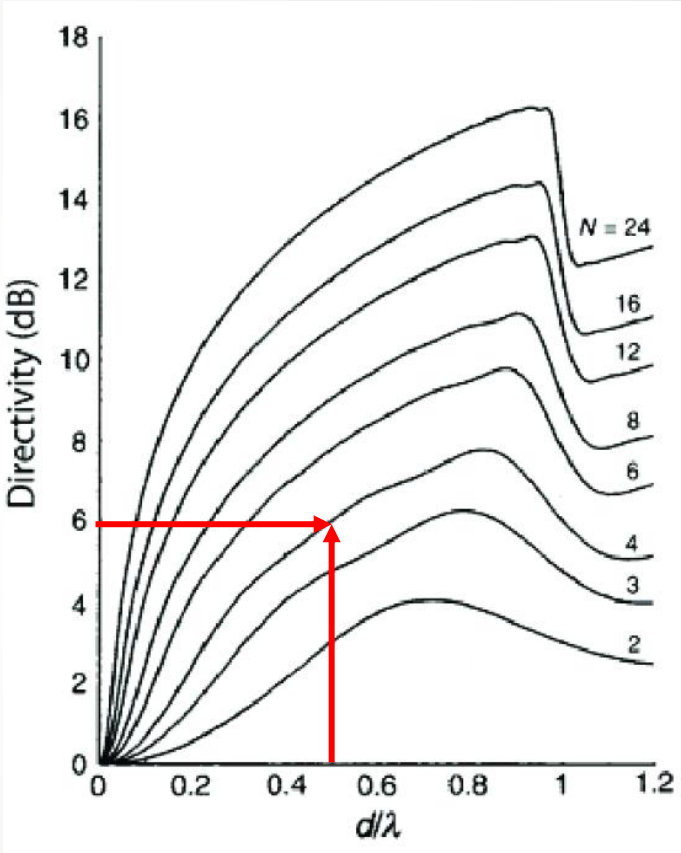
Dimension	Value [mm]
Patch Length	4.7
Patch Width	3.9
Substrate Length (λ/2)	6
Substrate Width (λ/2)	6
Substrate Permittivity (RT/duroid® 5880) [F/m]	2.2
Substrate Thickness (0.0015λ)	0.18
SMA Pin Diameter	0.25
SMA Dielectric Diameter	2.4
SMA Dielectric Permittivity (Air) [F/m]	1.0006
Probe Feed X (from center)	0
Probe Feed Y (from center)	1.4
Feed Length	5

ARRAY DETAILS

Goal of around 11-14dB directivity

HPBW Horizontal ~30/25deg

HPBW Vertical ~80/75deg



[6]

5. INVESTIGATING THE IMPEDANCE AND RADIATION CHARACTERISTICS USING SIMULATION

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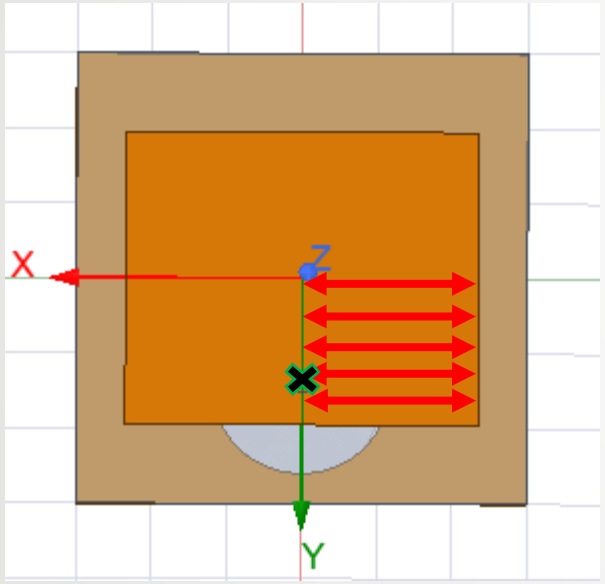
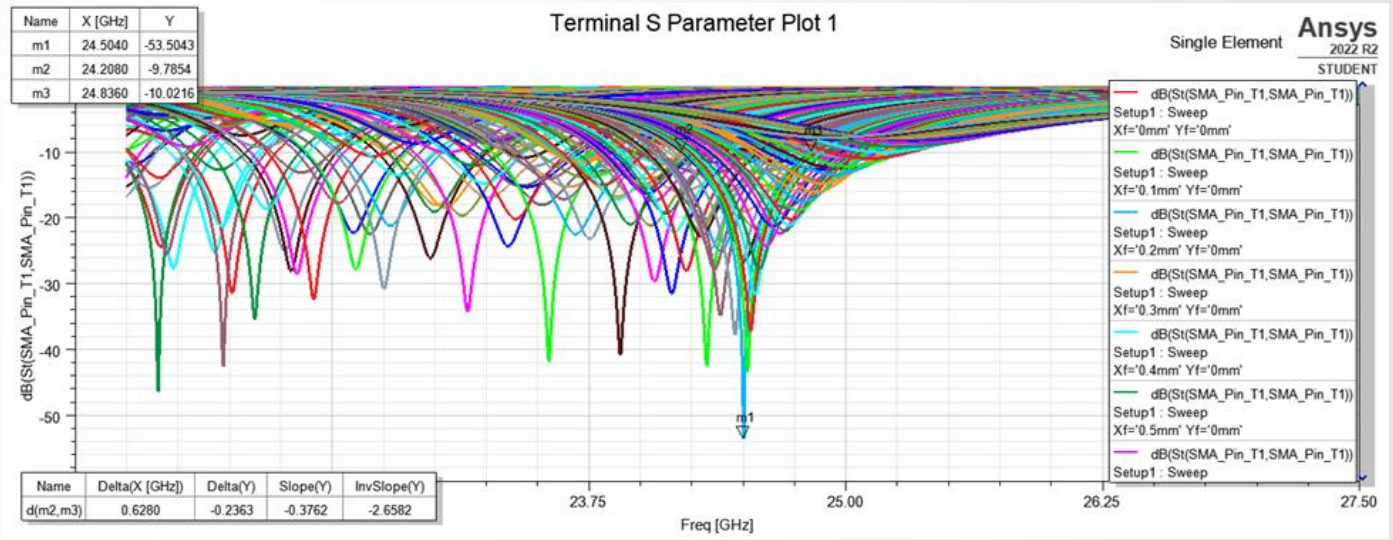
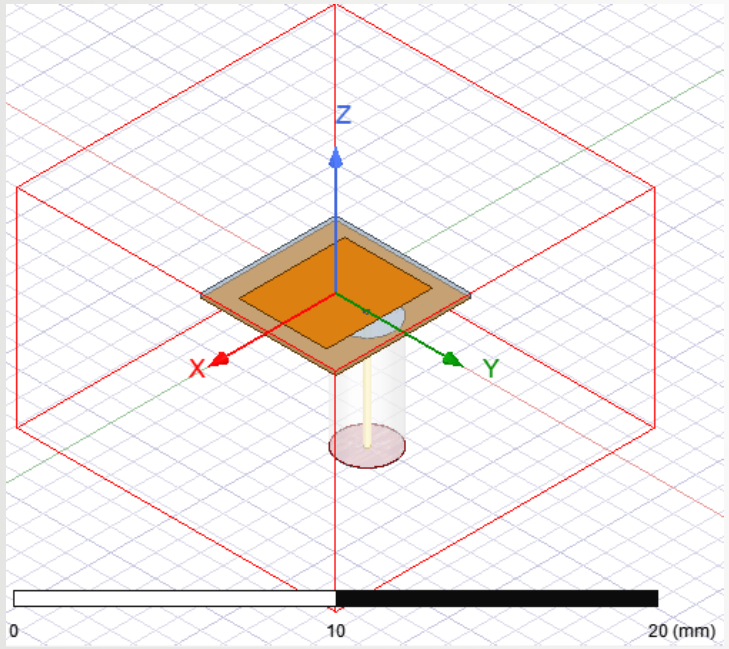
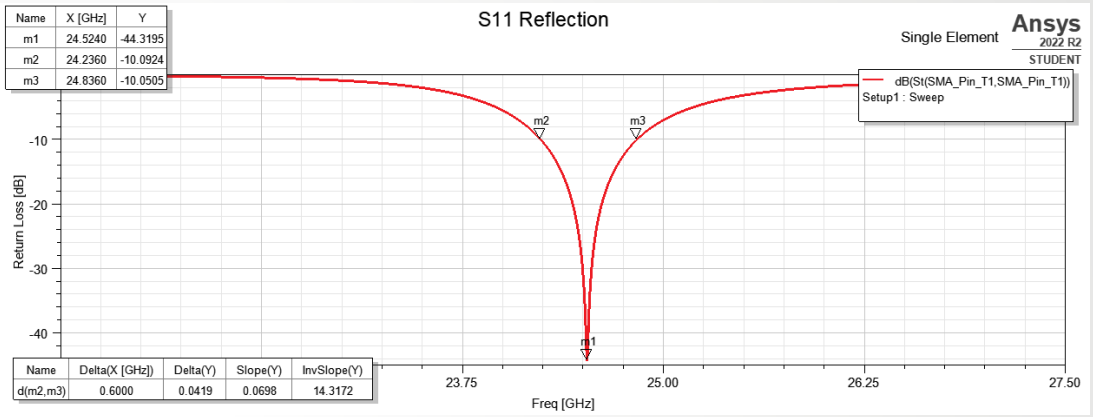
SINGLE ELEMENT IMPEDANCE MATCH

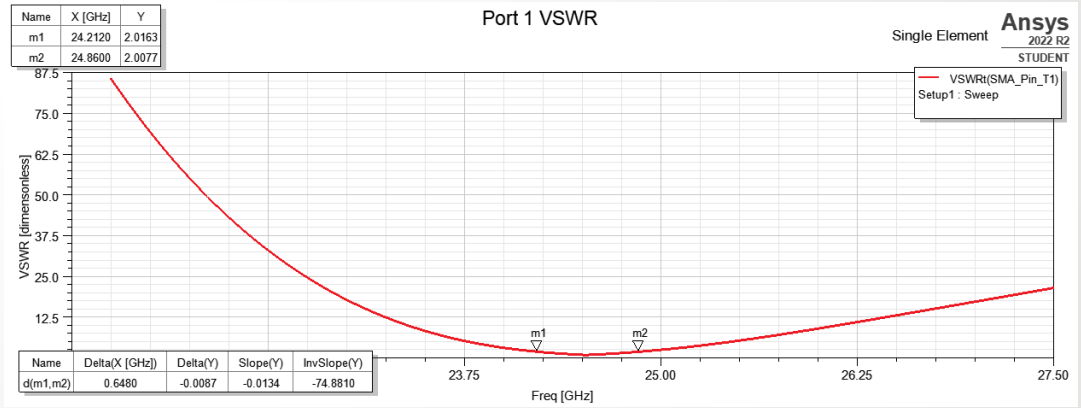




SINGLE ELEMENT IMPEDANCE MATCH



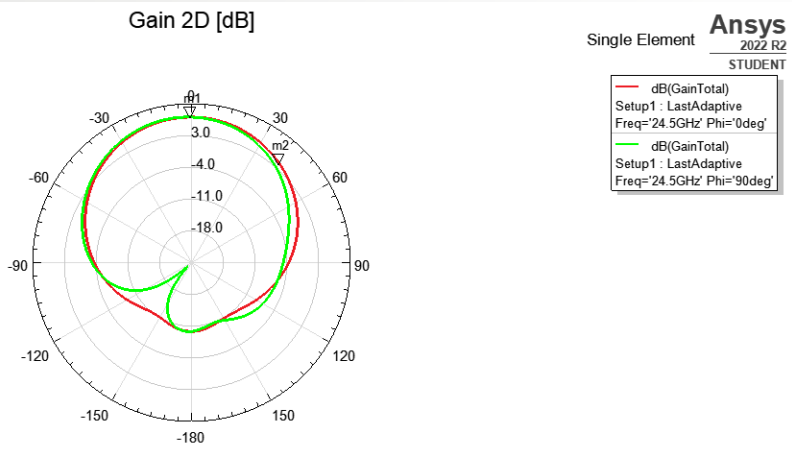




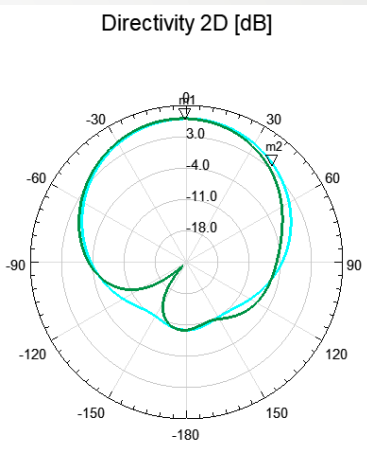
Bandwidth ~650MHz (24.21-24.86 GHz)

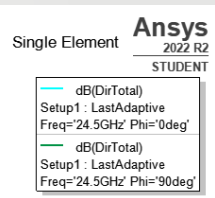
SINGLE ELEMENT GAIN AND DIRECTIVITY

Name	Theta [deg]	Ang	Mag
m1	0	4.9738E-13	7.0593
m2	42	42.0000	4.1208



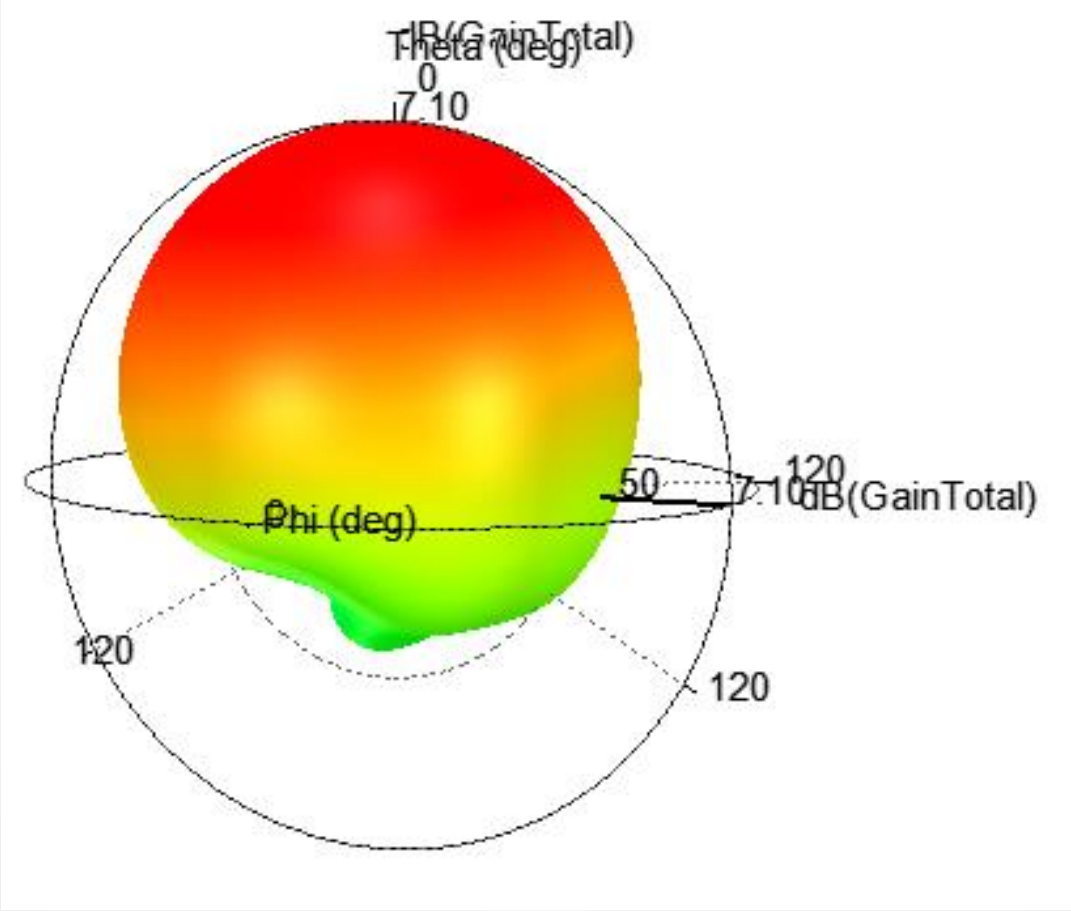
Name	Theta [deg]	Ang	Mag
m1	0	4.9738E-13	7.0537
m2	42	42.0000	4.1151



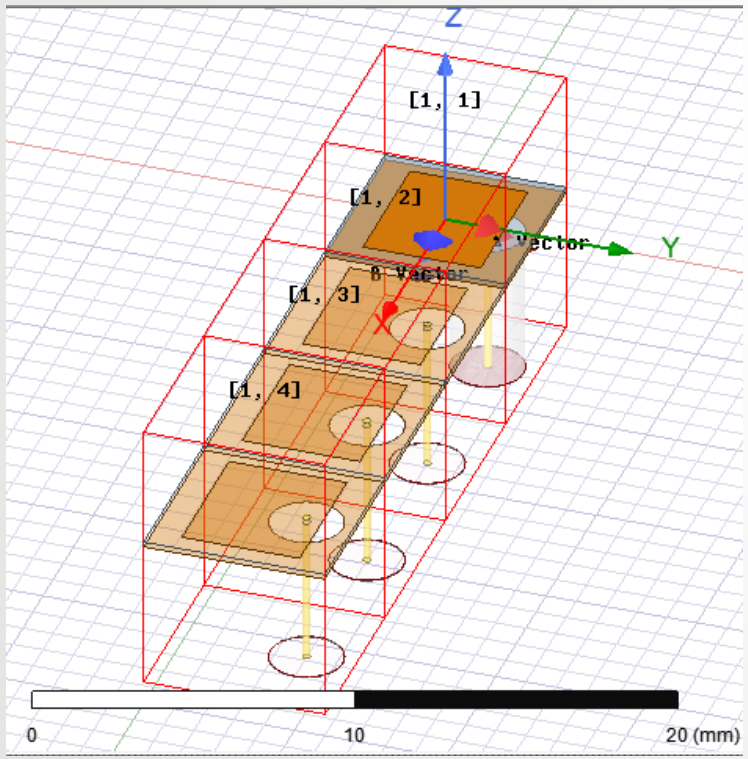


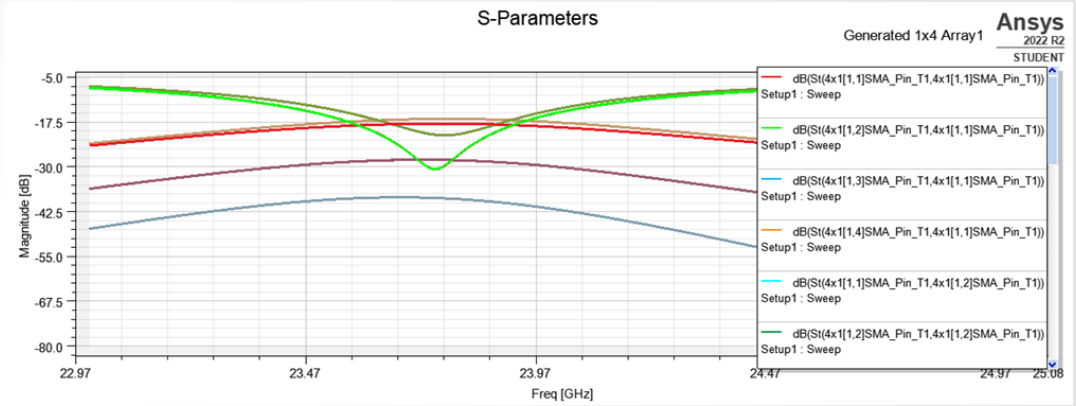
Directivity ≈ 7 dB
Gain ≈ 7 dB
HPBW Vertical and Horizontal ≈ 84deg

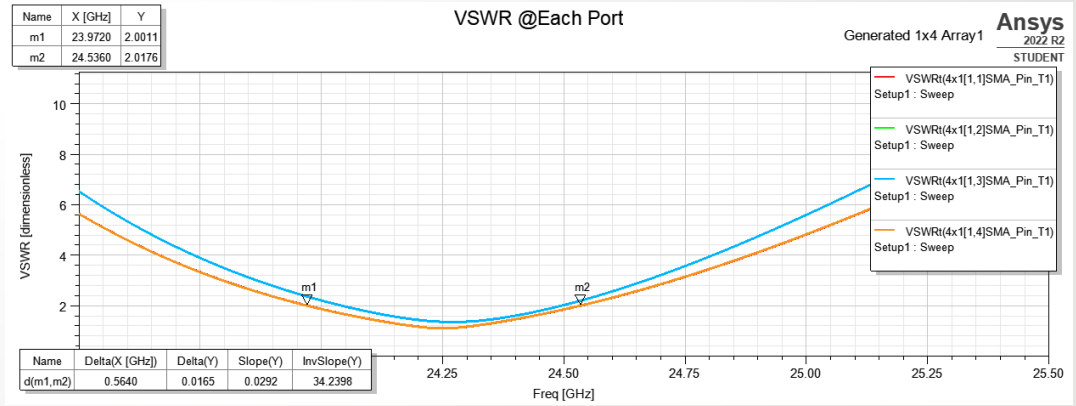
SINGLE ELEMENT 3D GAIN VISUALIZATION



4X1 LINEAR ARRAY DESIGN + PORT MATCHES/ISOLATIONS



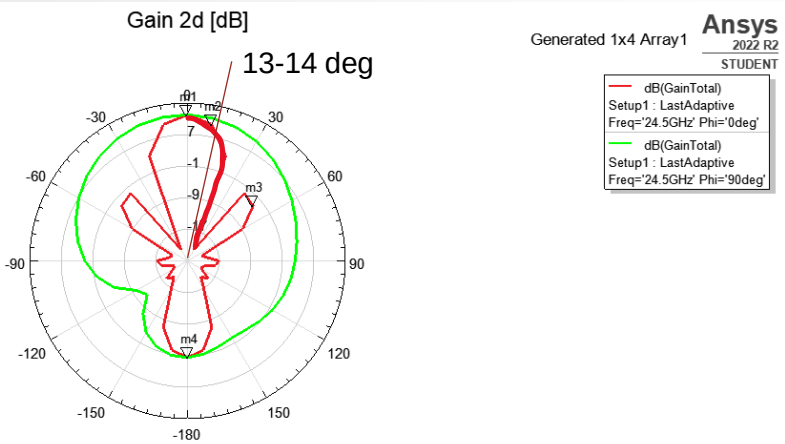




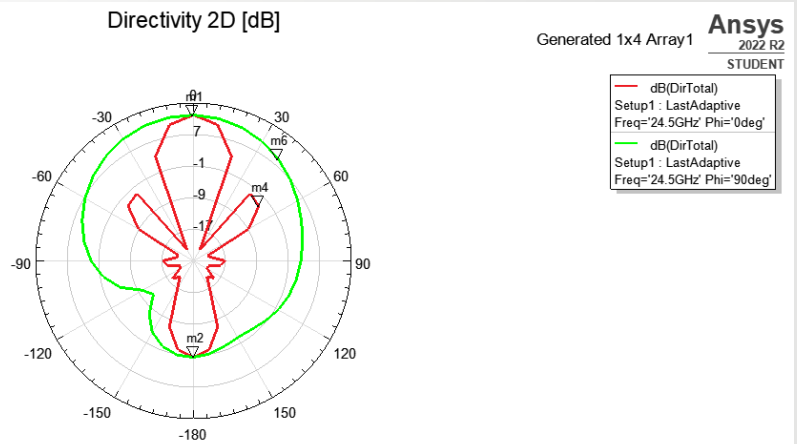
Bandwidth ~565MHz (23.97-24.54 GHz)

4X1 LINEAR ARRAY GAIN AND DIRECTIVITY

Name	Theta [deg]	Ang	Mag
m1	0	4.9738E-13	12.0392
m2	10	10.0000	10.1267
m3	50	50.0000	-3.2978
m4	-180	-180.0000	-0.4888

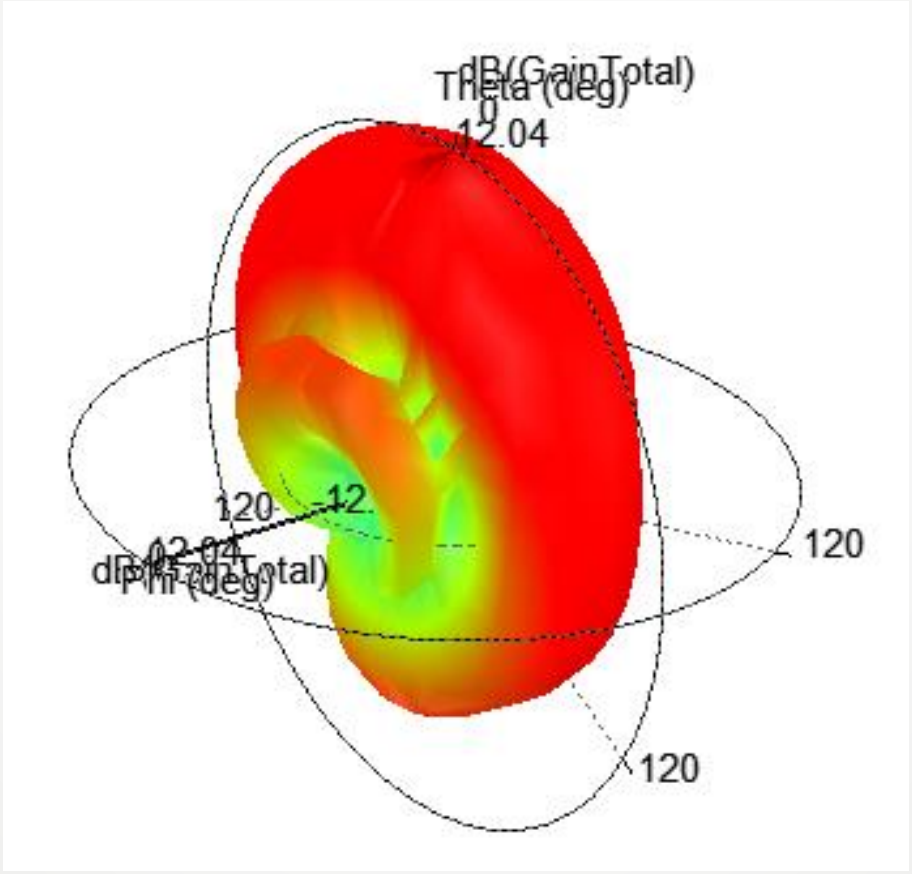


Name	Theta [deg]	Ang	Mag
m1	0	4.9738E-13	11.9620
m2	-180	-180.0000	-0.5659
m4	50	50.0000	-3.3749
m6	40	40.0000	8.5492

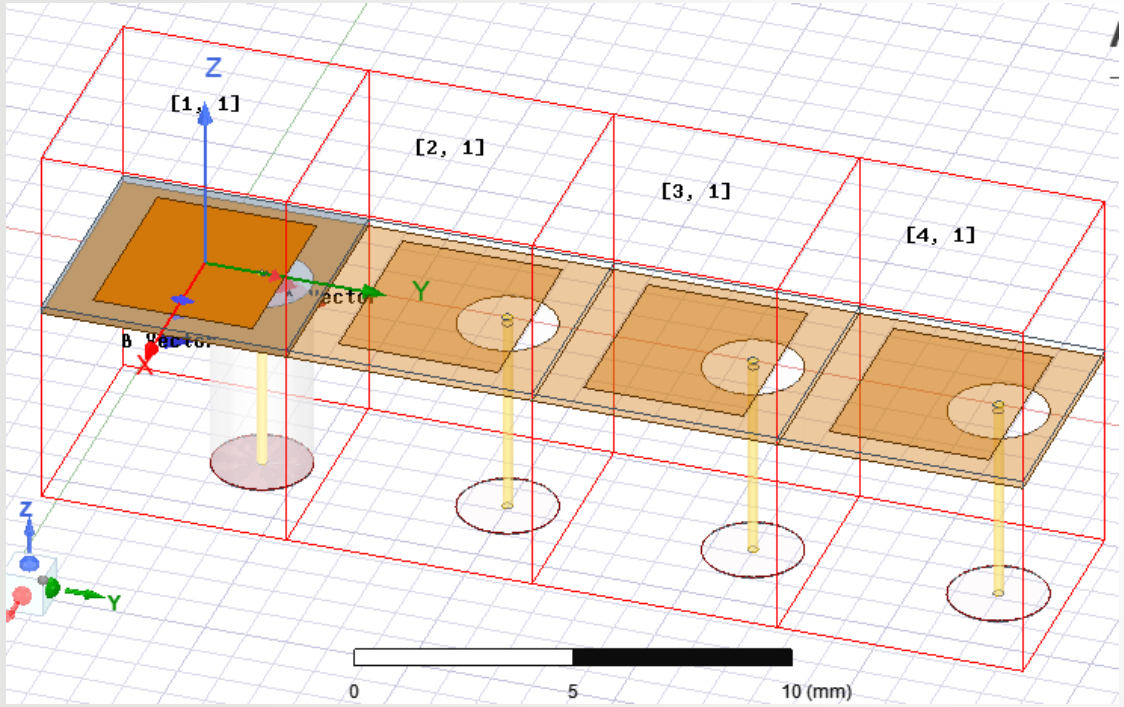


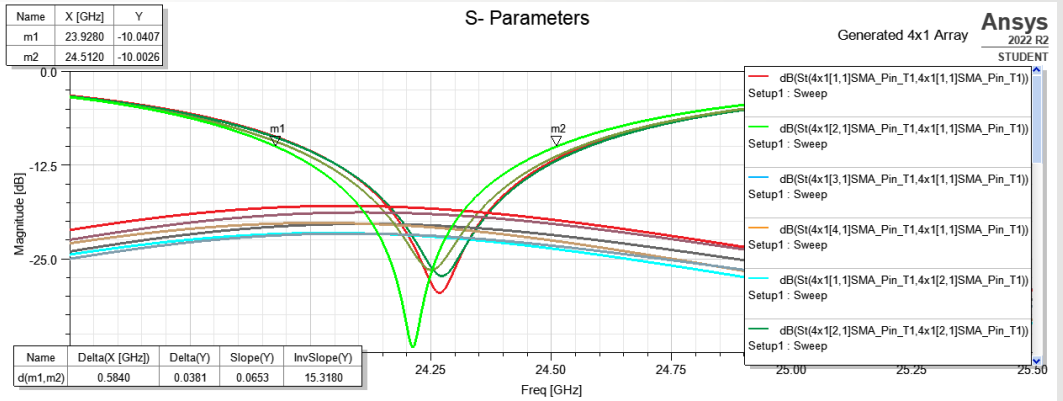
Directivity ≈ 12 dB
Gain ≈ 12 dB
HPBW Vertical ≈ 76deg
HPBW Horizontal ≈ 26deg

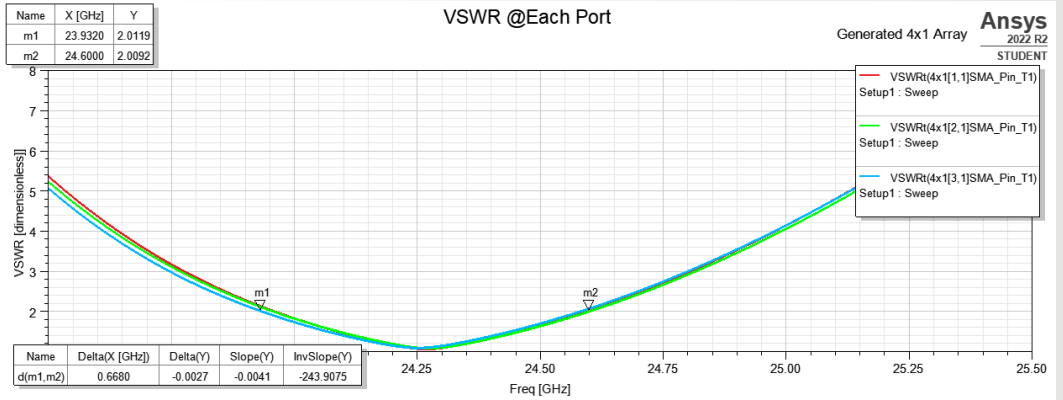
4X1 ARRAY 3D GAIN VISUALIZATION



1X4 LINEAR ARRAY DESIGN + PORT MATCHES/ISOLATIONS



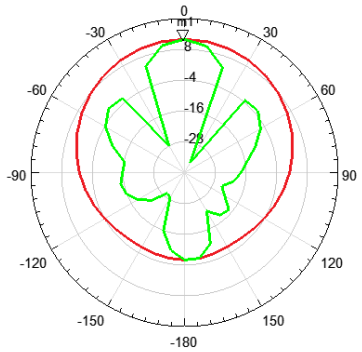


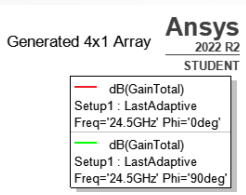


Bandwidth ~670MHz (23.93-24.51 GHz)

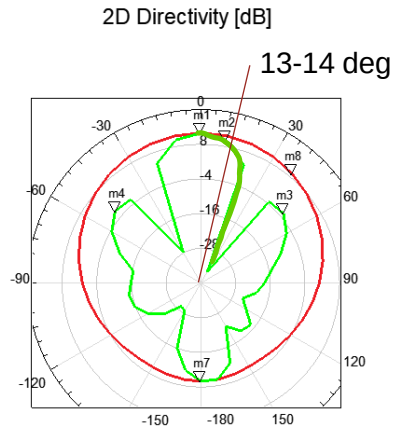
1X4 LINEAR ARRAY GAIN AND DIRECTIVITY

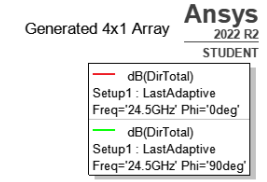
Name	Theta [deg]	Ang	Mag
m1	0	4.9738E-13	11.9399





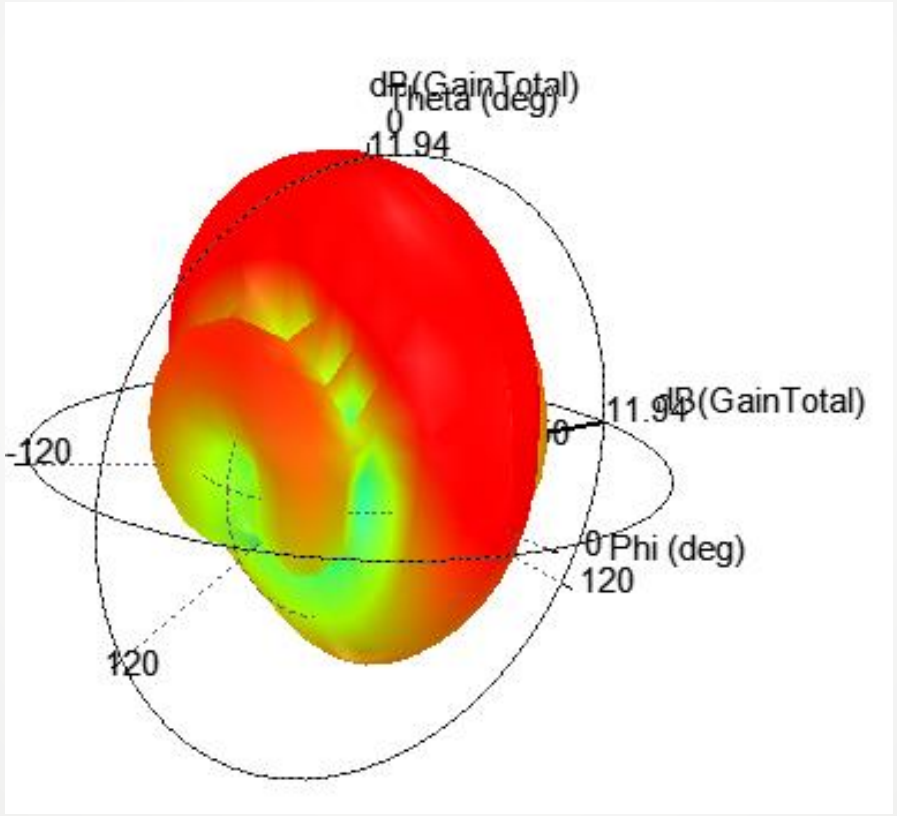
Name	Theta [deg]	Ang	Mag
m1	0	4.9738E-13	11.8992
m2	10	10.0000	9.9555
m3	50	50.0000	-2.6308
m4	-50	-50.0000	-1.2892
m7	180	180.0000	-5.9995
m8	40	40.0000	9.2519





Directivity ≈ 12 dB
Gain ≈ 12 dB
HPBW Vertical ≈ 84deg
HPBW Horizontal ≈ 26deg

1X4 ARRAY 3D GAIN VISUALIZATION



FINAL CHOICE AND SPEC CHECK

Reasoning:

Directivity ≈ 12 dB

Gain ≈ 12 dB

HPBW Vertical ≈ 84deg (+8 deg diff)

HPBW Horizontal ≈ 26deg

Bandwidth ≈ 670 MHz (+105MHz diff)

More consistent matching and isolation

Goal of around 11-14dB directivity ✓

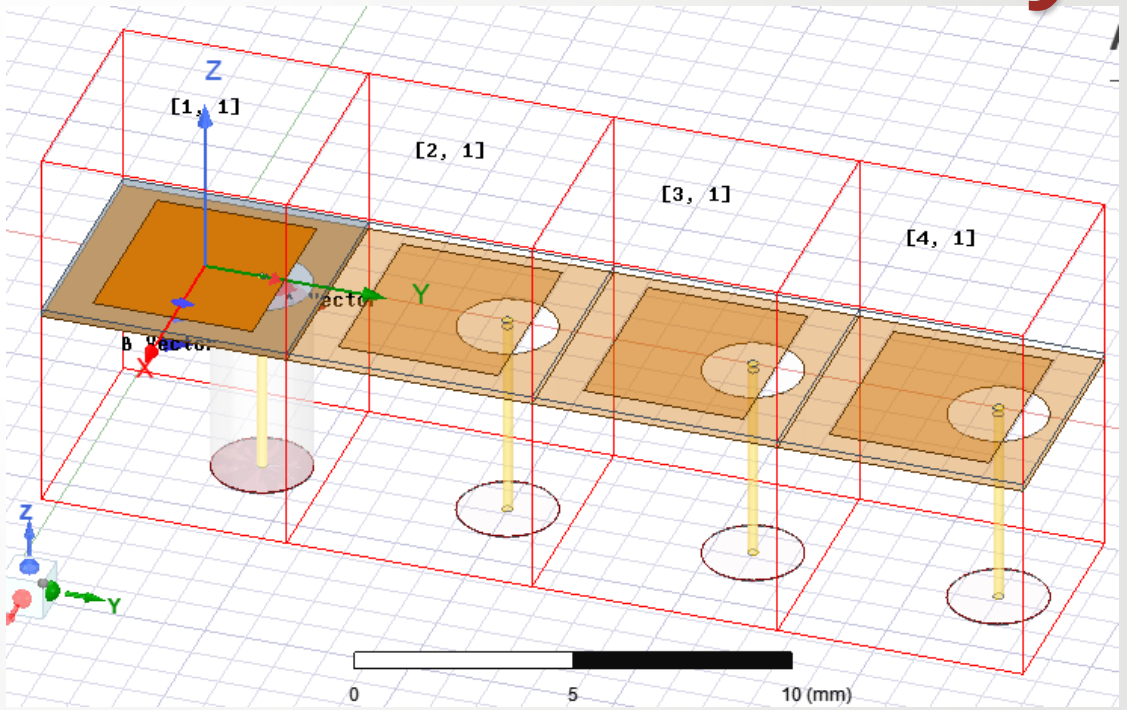
Typically, between 8-20dB of gain ✓

HPBW Horizontal ~30deg ✓

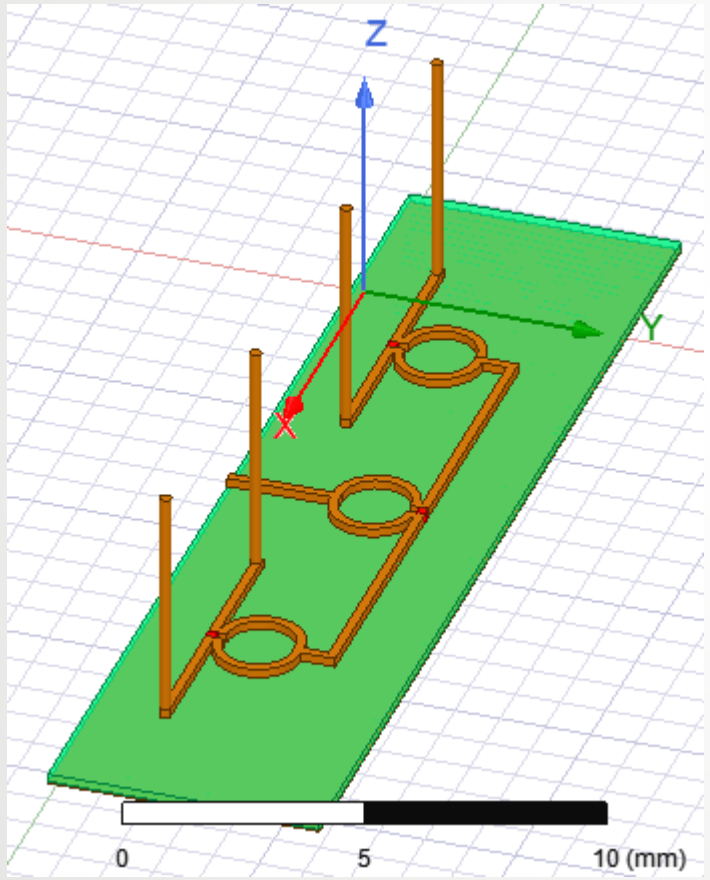
HPBW Vertical ~75deg ✓

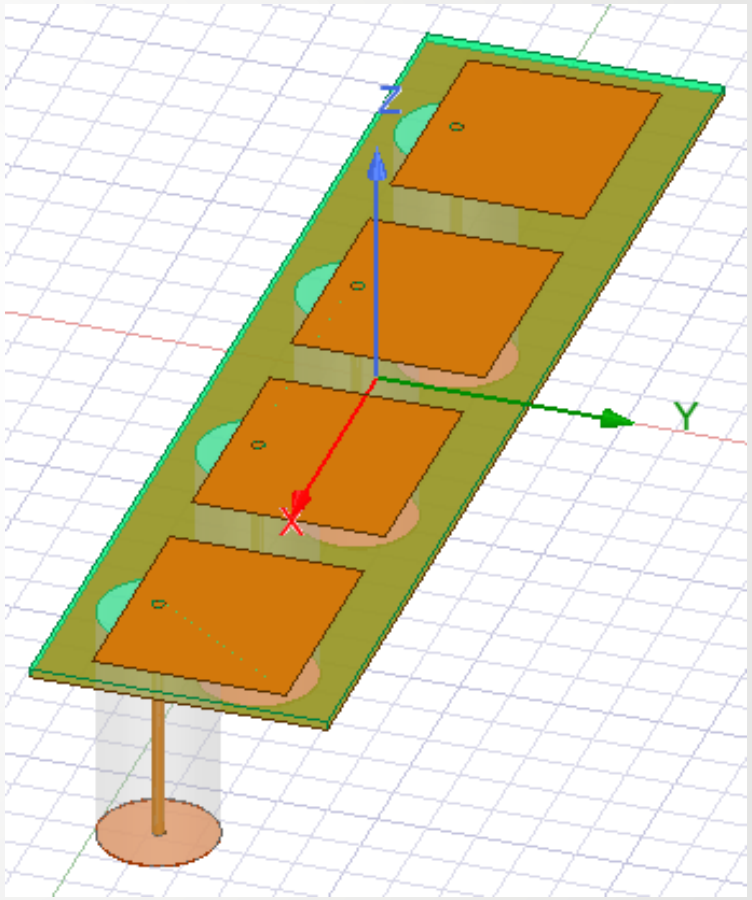
Aiming for at least 500 MHz Bandwidth ✓

1x4 Linear Array



6. HONORABLE MENTIONS





REFERENCES

[1] https://starry.com/technology

[2] https://support.starry.com/hc/en-us/articles

[3] https://web.wpi.edu/Pubs/E-project/Available/E-project-042811-161838/unrestricted/ChuckFungFinalMQPpaper2.pdf

[4] https://www.fcc.gov/sites/default/files/wireless/auctions/data/bandplans/24band.pdf

[5] ***DIRECTIONAL PATCH ANTENNA ARRAY DESIGN FOR DESKTOP WIRELESS INTERNET***

[6] ***Typical Array Geometries and Basic Beam Steering Methods 2.1 Introduction***