# Humax HR54R1-500

## HW1.2 Passive Measurement Report

Date: October, 2017

Prepared By: Alden Rush

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# Outline

- Airgain introduction
- ANT Placement
- Measurement set-up guide for electrical test @ Agilent
- Electrical test data
  - S-parameter
  - ANT Efficiency & Peak gain
- Measurement set-up guide for electrical test @ SATIMO
  - Radiation test data
- Performance Summary
- Appendix



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# "Airgain" introduction

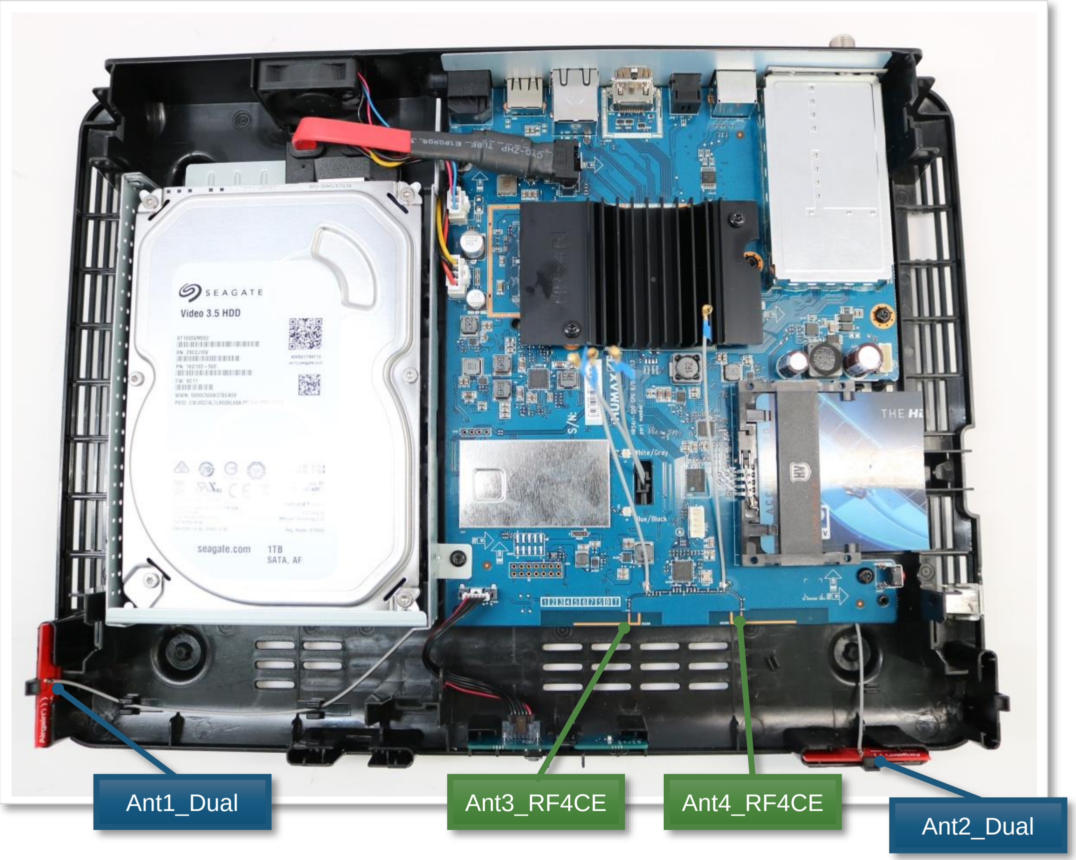
**A leading provider of wireless technologies that solve critical connectivity needs**

- Founded 2003
- IPO 2016 (NASDAQ: AIRG)
- San Diego, CA Headquarters
- Global Sales & Design Centers
- ~145 Employees†
- >250 Patents & Applications
- >1000 Product SKUs


† Indicates employees and dedicated representatives

Address : Airgain 3611 Valley Centre Drive, Ste. 150 San Diego, CA 92130 USA

# Antenna Placement




| Antenna # | Part Number |
|---|---|
| Ant1_Dual | N2425HMHRA-290 |
| Ant2_Dual | N2425HMHRD-190 |
| Ant3_RF4CE | N/A |
| Ant4_RF4CE | N/A |

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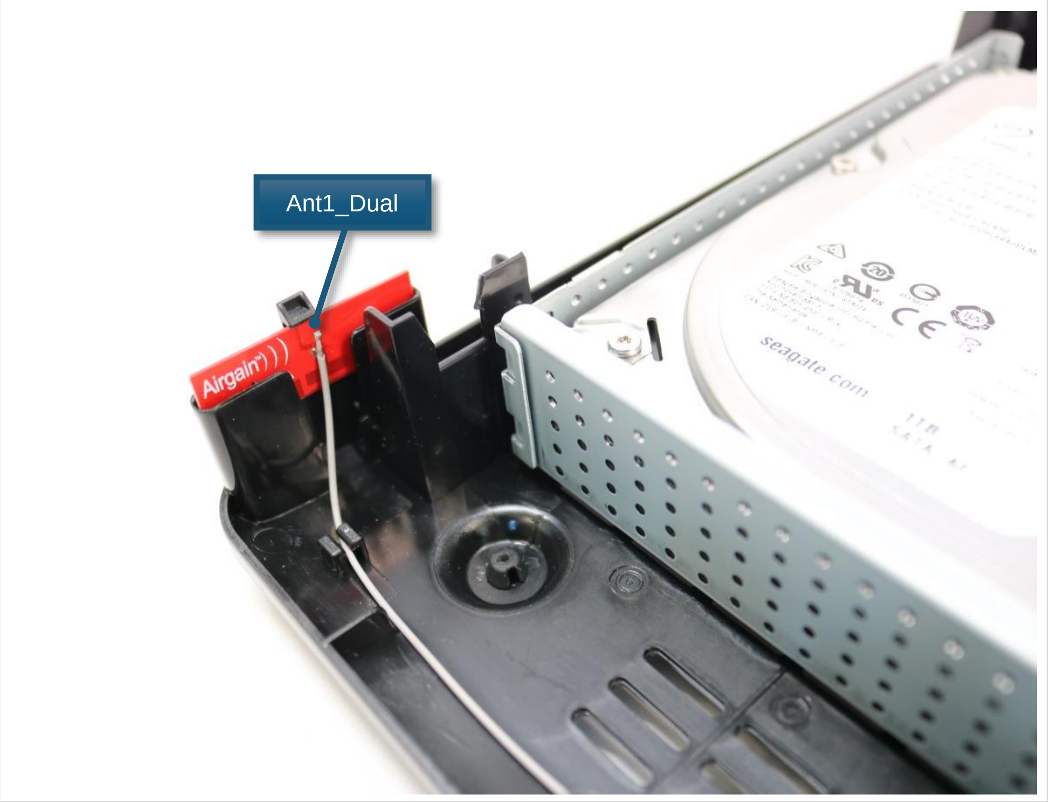
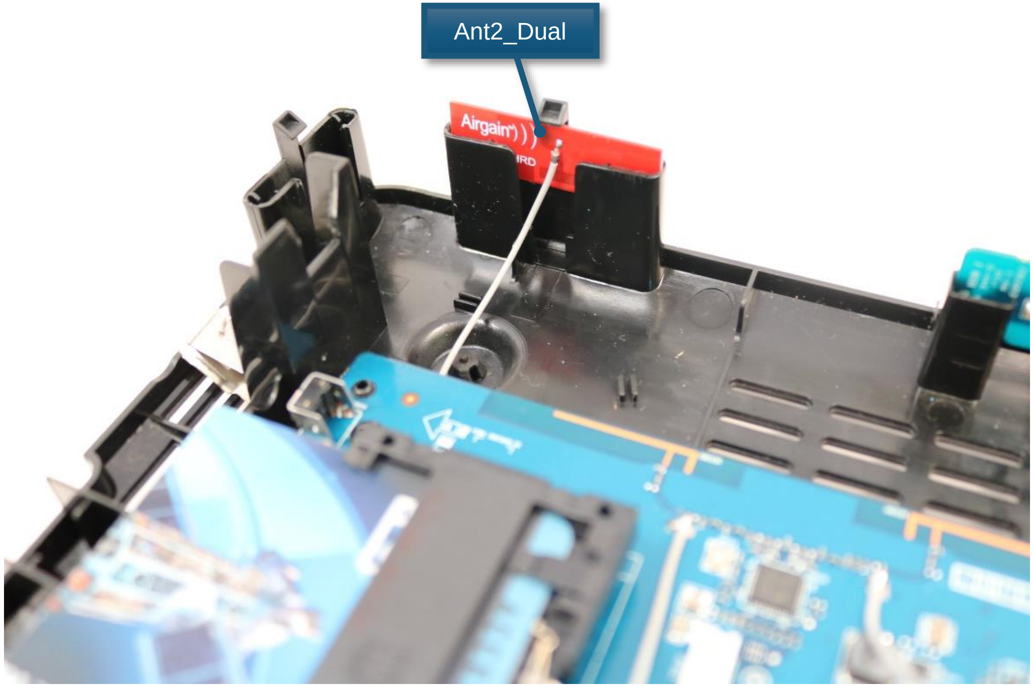
# Ant1_Dual Placement




| Antenna # | Part Number |
| --- | --- |
| Ant1_Dual | N2425HMHRA-290 |

# Ant2_Dual Placement




| Antenna # | Part Number |
|---|---|
| Ant2_Dual | N2425HMHRD-190 |



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# Measurement set-up for Electrical test @ Agilent


- **Test Equipment**

- Network Analyzer Model Name：Agilent E5071B
- Calibration kits
- Test cables
- SMA to IPEX adaptor

- Test process

- Do the full SOL calibration at the end of VNA cable.
- Set the limit line and save the calibration file for next time continent recall.
- Install an SMA to IPEX adaptor at the end of the VNA cable.
- Put the DUT on the foam support, make sure there is no reflection block surroundings.
- Connect the VNA cable to the antennas that already through out the device enclosure. Save the data and disconnect the cable.
- Repeat above steps unit all antennas to be tested.
- Test is complete.

# Instrument Calibration Data

| Device | Maker | Serial No (if applicable) | Calibrated Date | Calibrated Until |
|---|---|---|---|---|
| Chamber | Satimo starlab | 1102283-0006 | 13-Feb-2017 | 13-Feb-2018 |
| Noise Figure Analyzer | N8973A | GB39490802 | 13-Feb-2017 | 13-Feb-2018 |
| Network Analyzer | E5071C | MY46522087 | 13-Feb-2017 | 13-Feb-2018 |
| Network Analyzer | E5071B | MY42100196 P8369229832942 | 13-Feb-2017 | 13-Feb-2018 |
| Network Analyzer | E5071B | MY42402824 | 13-Feb-2017 | 13-Feb-2018 |
| SPECTRUM Analyzer | 8562E | 3921A00827 | 13-Feb-2017 | 13-Feb-2018 |
| SPECTRUM Analyzer | MS2602A | 6200003028 | 13-Feb-2017 | 13-Feb-2018 |
| SIGNAL GENERATOR | E4421B | P8369229828429 | 13-Feb-2017 | 13-Feb-2018 |
| Digital Calipers | (0-300)mm/0.01mm | 301483 | 13-Feb-2017 | 13-Feb-2018 |
| Digital Calipers | (0-150)mm/0.01mm | K16C298377 | 13-Feb-2017 | 13-Feb-2018 |
| Logic Analyzer | VNA(HP8753D)Logic Analyzer | 3410A05162 | 13-Feb-2017 | 13-Feb-2018 |



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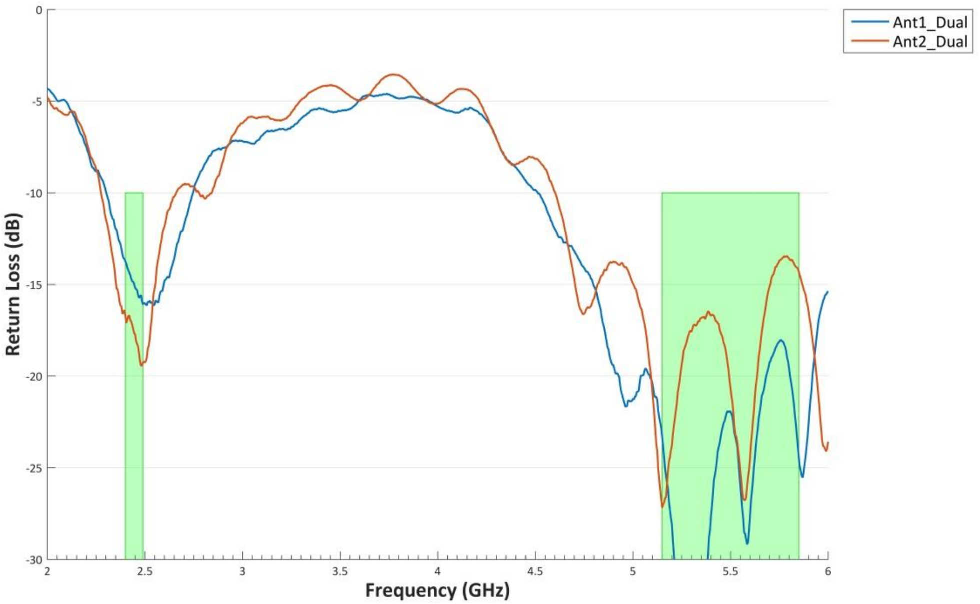
# S-Parameter – Return Loss for Dual Band Antennas




## KEY OBSERVATIONS

| Antenna | Return Loss (dB) | | | |
|---|---|---|---|---|
| | 2.4 GHz | 2.49 GHz | 5.15 GHz | 5.85 GHz |
| Ant1_Dual | -13.7 | -16.1 | -23.3 | -24.4 |
| Ant2_Dual | -16.7 | -19.3 | -27.2 | -14.3 |



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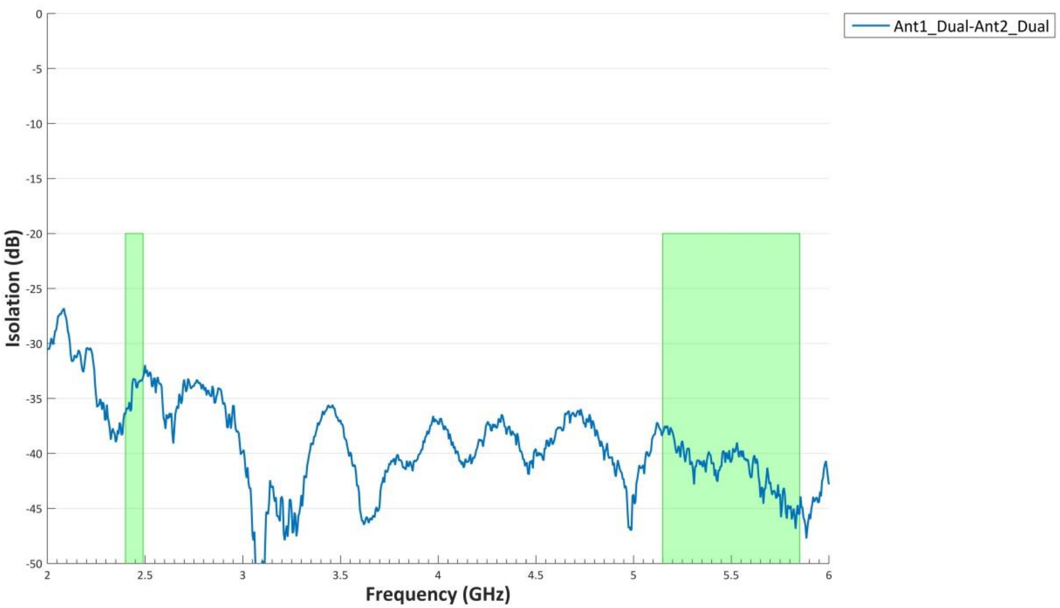
# S-Parameter – Isolation Between Dual Band Antennas




## KEY OBSERVATIONS

| Antenna | Minimum Isolation (dB) | |
|---|---|---|
| | 2.4GHz-2.49GHz | 5.15GHz-5.85GHz |
| Ant1_Dual-Ant2_Dual | -33.1 | -37.5 |

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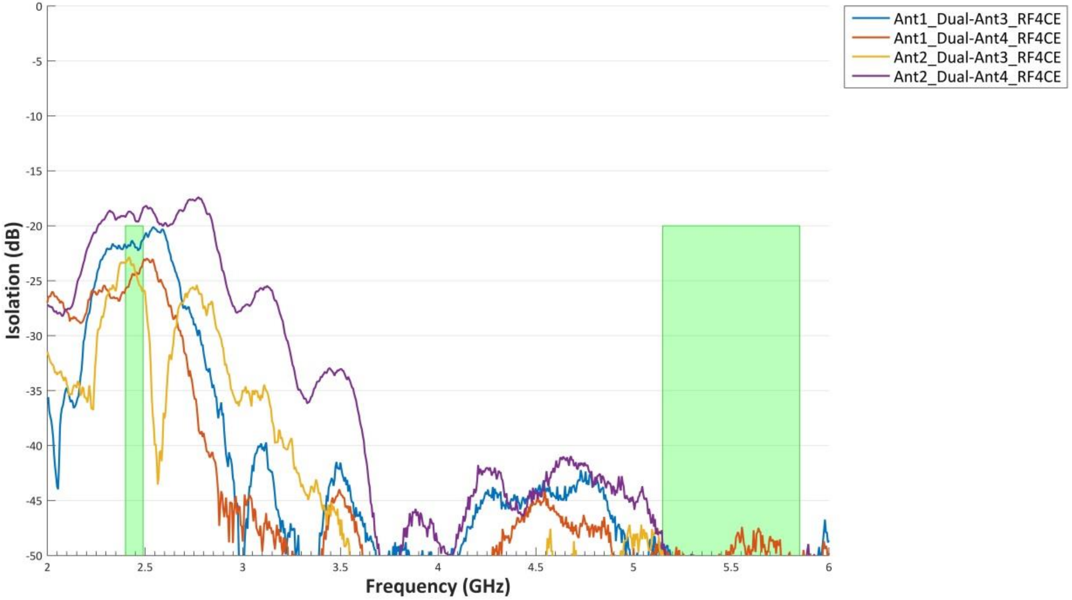
# S-Parameter – Isolation Between Dual Band and RF4CE Antennas




## KEY OBSERVATIONS

| Antenna | Minimum Isolation (dB) | |
|---|---|---|
| | 2.4GHz-2.49GHz | 5.15GHz-5.85GHz |
| Ant1_Dual-Ant3_RF4CE | -21.3 | -49.1 |
| Ant1_Dual-Ant4_RF4CE | -23.3 | -47.4 |
| Ant2_Dual-Ant3_RF4CE | -22.9 | -49.9 |
| Ant2_Dual-Ant4_RF4CE | -18.4 | -48.9 |

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# Antenna Efficiency – 2.4GHz Wi-Fi Band

| Frequency (MHz) | Ant1_Dual (%) | Ant2_Dual (%) |
|---|---|---|
| 2400 | 64 | 69 |
| 2410 | 63 | 68 |
| 2420 | 63 | 67 |
| 2430 | 63 | 67 |
| 2440 | 64 | 68 |
| 2450 | 66 | 70 |
| 2460 | 68 | 72 |
| 2470 | 70 | 74 |
| 2480 | 70 | 75 |
| 2490 | 70 | 75 |
| Average | 66 | 71 |

# Antenna Efficiency – 5GHz Wi-Fi Band

| Frequency (MHz) | Ant1_Dual (%) | Ant2_Dual (%) |
|---|---|---|
| 5150 | 60 | 66 |
| 5200 | 61 | 67 |
| 5300 | 61 | 66 |
| 5400 | 61 | 67 |
| 5500 | 57 | 62 |
| 5600 | 57 | 63 |
| 5700 | 59 | 64 |
| 5800 | 56 | 60 |
| 5850 | 59 | 62 |
| Average | 59 | 64 |



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# Antenna Peak Gain – 2.4GHz Wi-Fi Band

| Frequency (MHz) | Ant1_Dual (dBi) | Ant2_Dual (dBi) |
|---|---|---|
| 2400 | 2.1 | 4.0 |
| 2410 | 2.2 | 3.8 |
| 2420 | 2.3 | 3.7 |
| 2430 | 2.6 | 3.7 |
| 2440 | 2.7 | 3.7 |
| 2450 | 2.7 | 3.7 |
| 2460 | 2.8 | 3.8 |
| 2470 | 3.0 | 3.8 |
| 2480 | 3.1 | 3.8 |
| 2490 | 3.2 | 3.8 |

# Antenna Peak Gain – 5GHz Wi-Fi Band

| Frequency (MHz) | Ant1_Dual (dBi) | Ant2_Dual (dBi) |
|---|---|---|
| 5150 | 4.0 | 3.2 |
| 5200 | 3.8 | 3.7 |
| 5300 | 3.6 | 3.3 |
| 5400 | 3.6 | 4.1 |
| 5500 | 3.1 | 4.0 |
| 5600 | 3.4 | 4.2 |
| 5700 | 3.3 | 3.7 |
| 5800 | 3.9 | 3.6 |
| 5850 | 4.1 | 3.8 |



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# Gain Maximum direction indicator

| | Freq. MHz | 2400 | 2450 | 2490 |
|---|---|---|---|---|
| Ant1 | Peak Gain | 2.1 | 2.7 | 3.2 |
| | Peak Gain @ | Theta = 103 ; Phi = 277 | Theta = 167 ; Phi = 353 | Theta = 350 ; Phi = 187 |
| Ant2 | Peak Gain | 4.0 | 3.7 | 3.8 |
| | Peak Gain @ | Theta = 24 ; Phi = 15 | Theta = 115 ; Phi = 109 | Theta = 355 ; Phi = 254 |

| | Freq. MHz | 5150 | 5300 | 5700 | 5850 |
|---|---|---|---|---|---|
| Ant1 | Peak Gain | 4.0 | 3.6 | 3.3 | 4.1 |
| | Peak Gain @ | Theta = 260 ; Phi = 283 | Theta = 84 ; Phi = 260 | Theta = 232 ; Phi = 159 | Theta = 332 ; Phi = 174 |
| Ant2 | Peak Gain | 3.2 | 3.3 | 3.7 | 3.8 |
| | Peak Gain @ | Theta = 242 ; Phi = 220 | Theta = 26 ; Phi = 5 | Theta = 127 ; Phi = 117 | Theta = 247 ; Phi = 240 |


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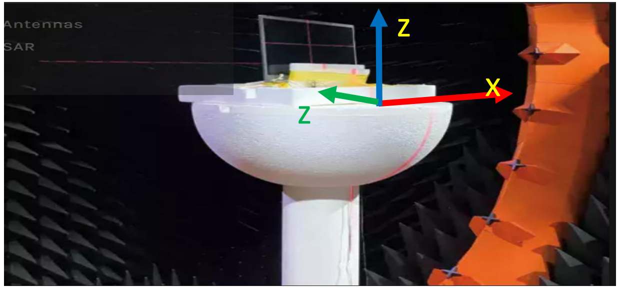
# Measurement set-up for radiation test @ SATIMO




- Test Equipment

- Model Name : **SATIMO Passive Measurement Ve. 1.8.0**

- Test process

- Position the DUT centralized inside the Chamber as shown above
- The Ethernet port face outside.
- Once positioned, the placement of DUT shall not change until the end of all radiated tests.
- Connect cable coming from DUT, designated as "Ant 1 " to the chamber's cable.
- Run sequence of radiated tests .
- Disconnect the chamber's cable from Ant 1 .
- Repeat this process for all RF ports of DUT.



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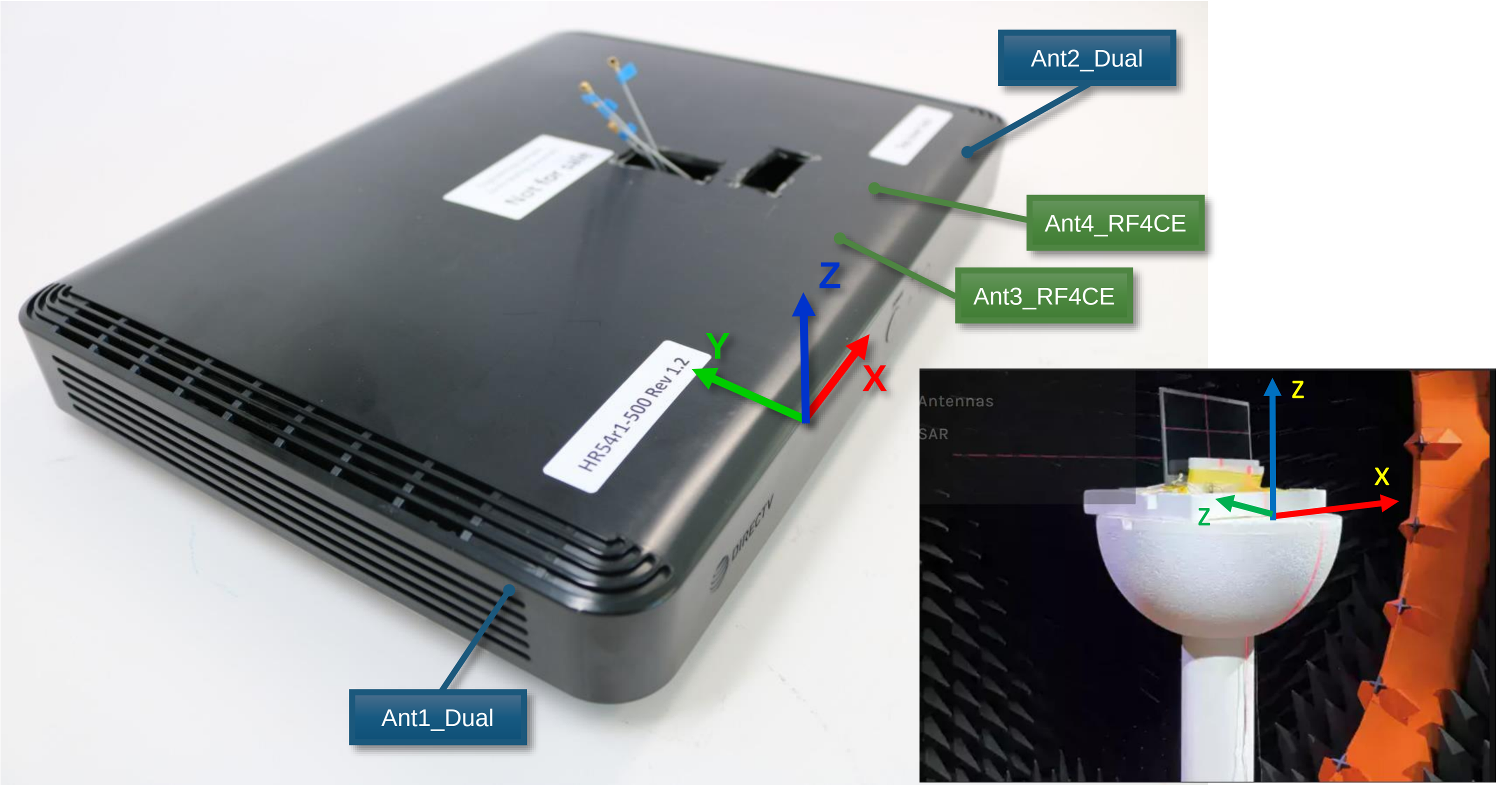
# Measurement set-up for radiation test @ SATIMO




*Orientation of Humax HR54R1 - 500*

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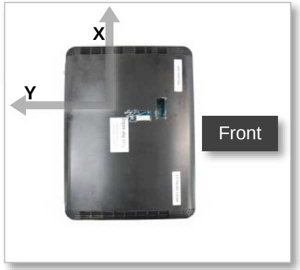
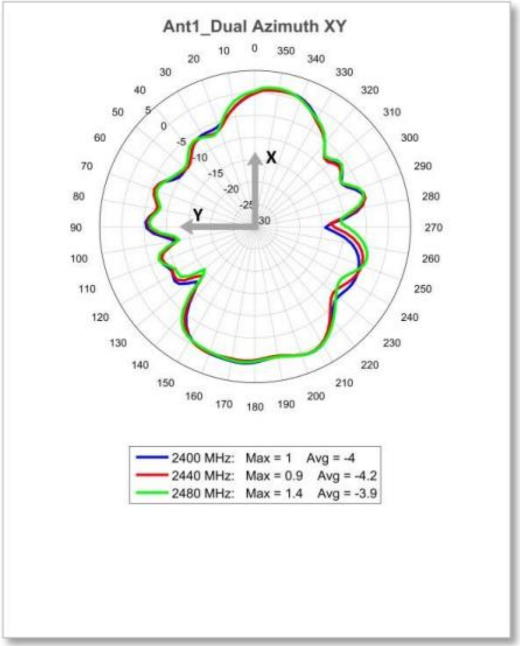
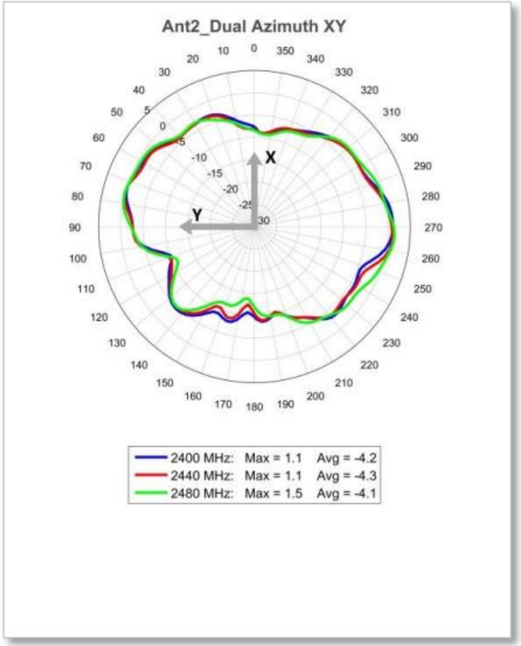
# Azimuth – 2.4GHz Wi-Fi Band




Ant1_Dual




Ant2_Dual



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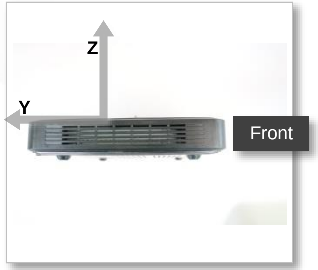
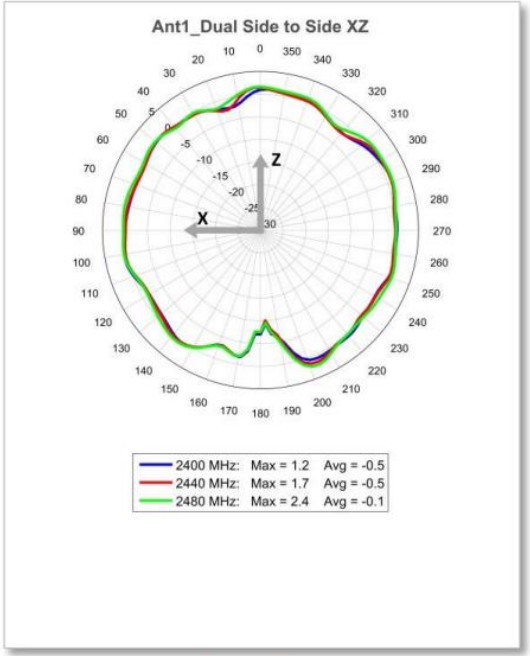
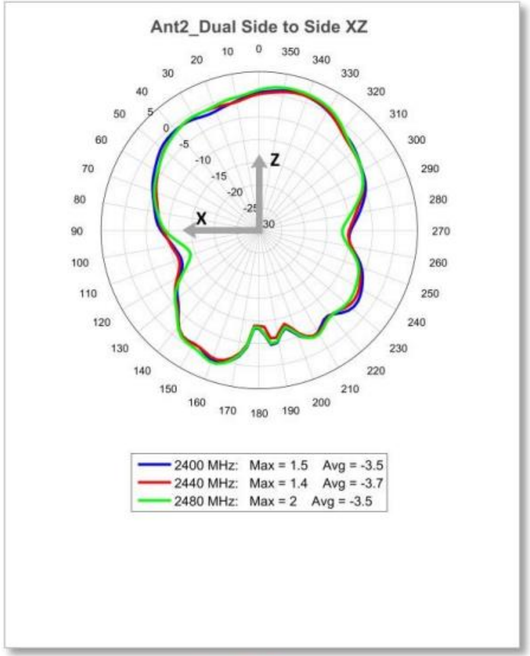
# Front to Back Elevation – 2.4GHz Wi-Fi Band




Ant1_Dual




Ant2_Dual



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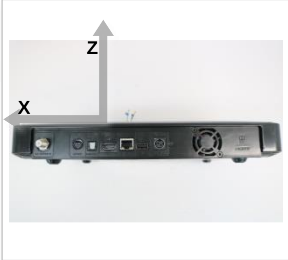
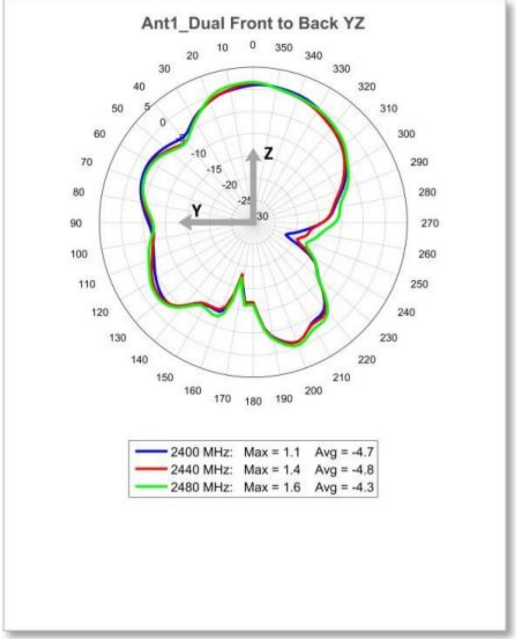
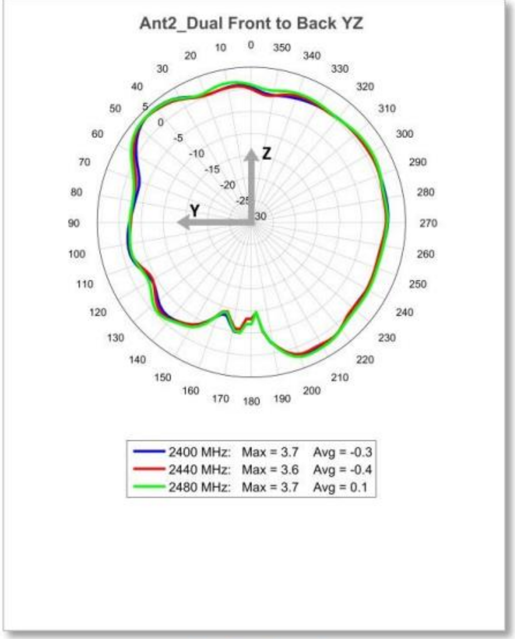
# Side to Side Elevation – 2.4GHz Wi-Fi Band




Ant1_Dual




Ant2_Dual

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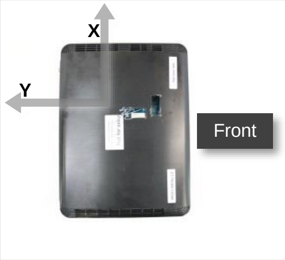
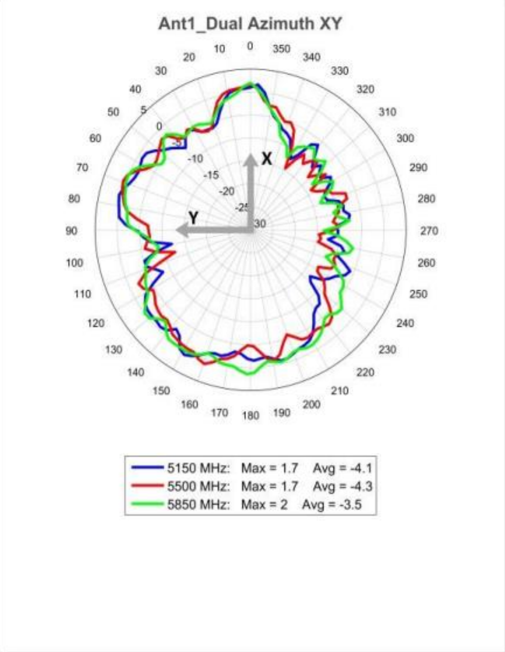
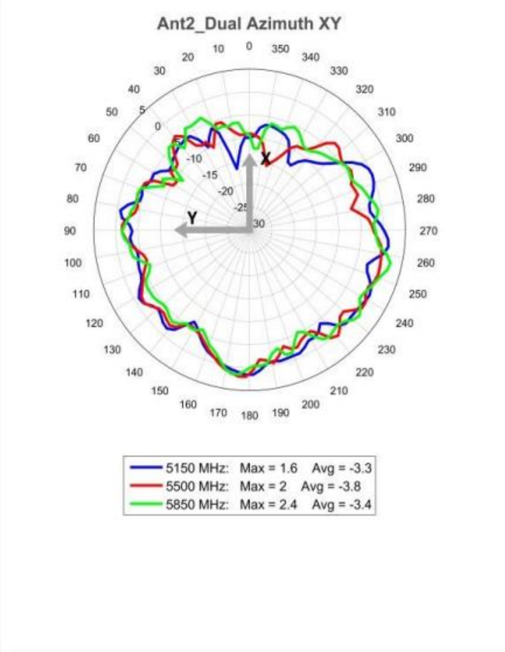
# Azimuth – 5GHz Wi-Fi Band




Ant1_Dual




Ant2_Dual



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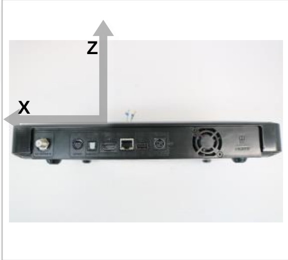
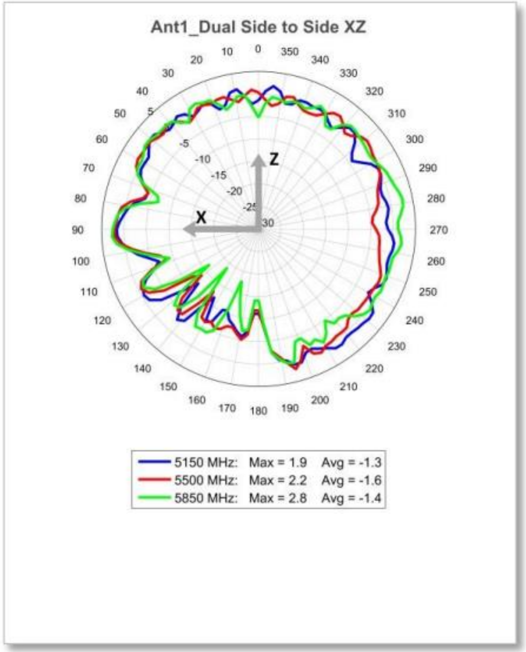
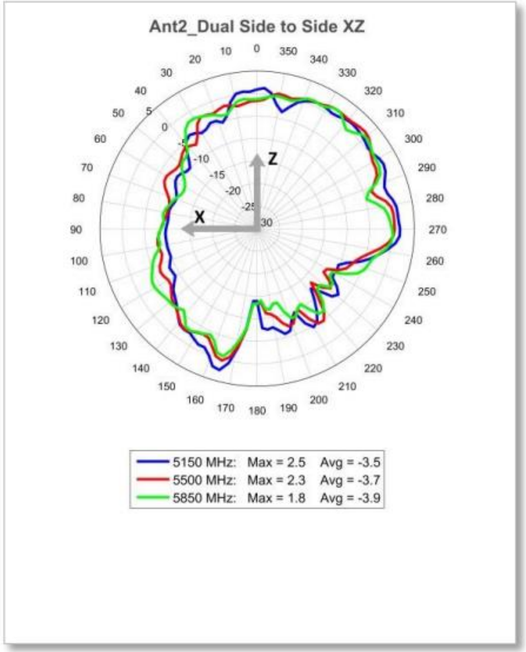
# Side to Side Elevation – 5GHz Wi-Fi Band




Ant1_Dual




Ant2_Dual

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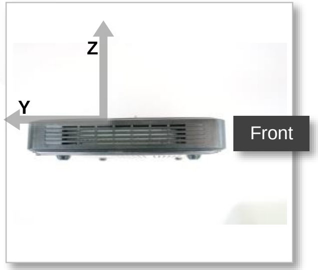
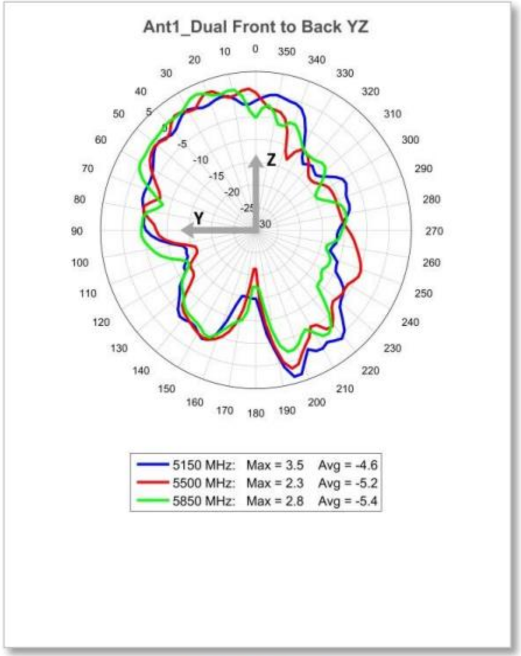
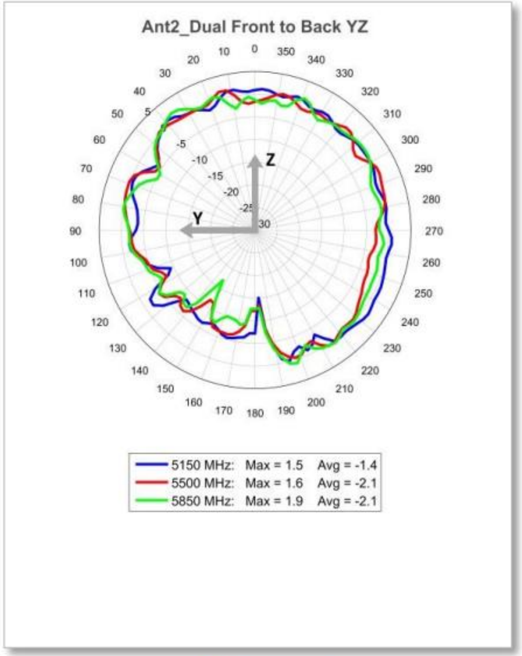
# Front to Back Elevation – 5GHz Wi-Fi Band




Ant1_Dual




Ant2_Dual



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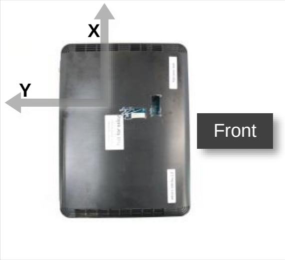
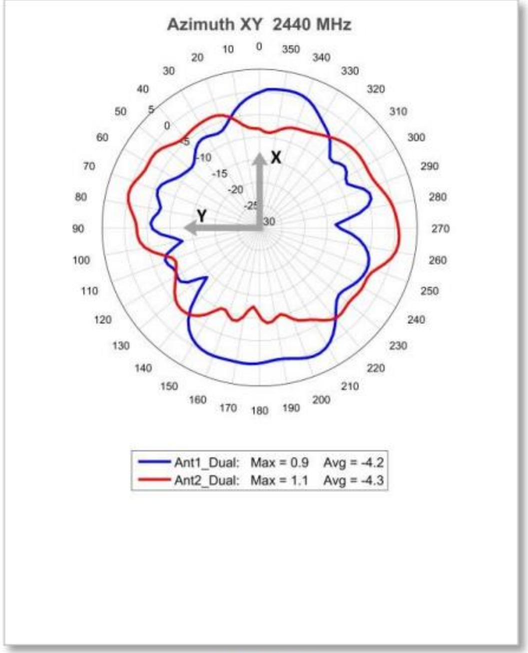
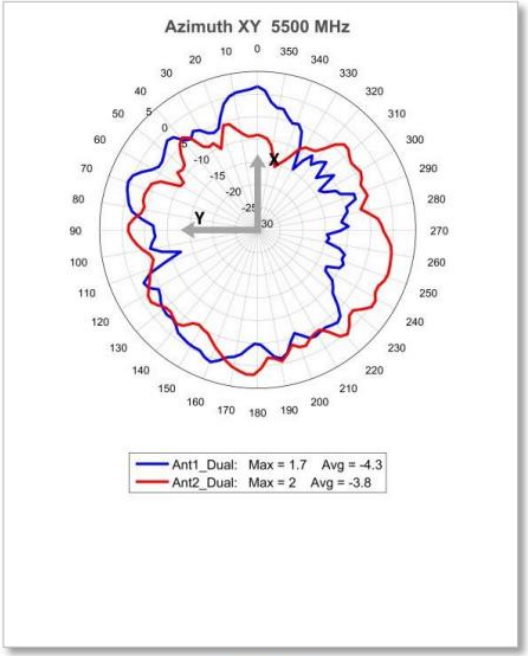
# System Coverage: Azimuth 2.44GHz and 5.5GHz




- Arrow show the max. gain direction

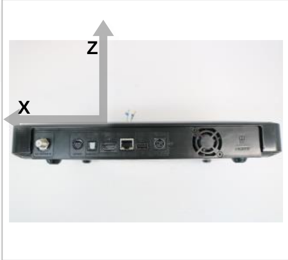



2.44 GHz

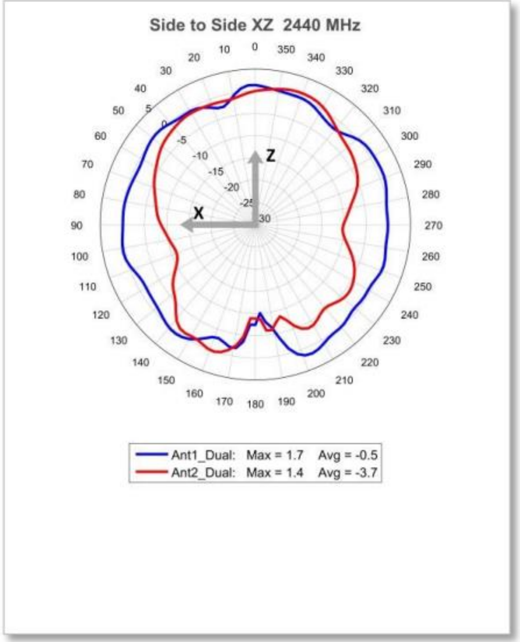



5.5 GHz

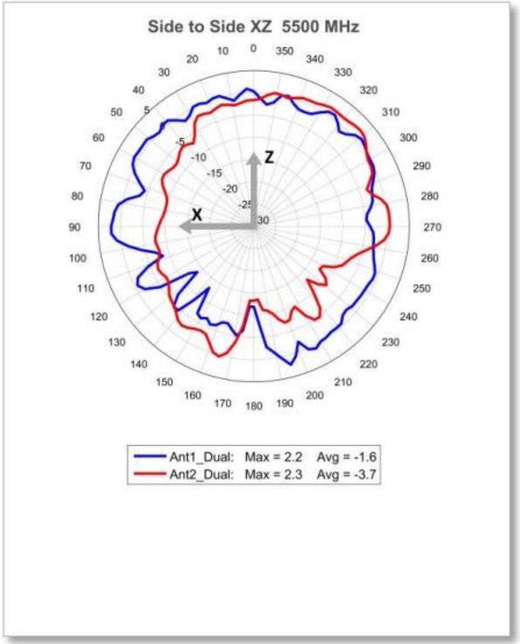
# System Coverage: Side to Side Elevation 2.44GHz & 5.5GHz




- Arrow show the max. gain direction




2.44 GHz




5.5 GHz

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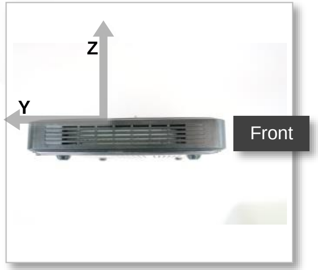
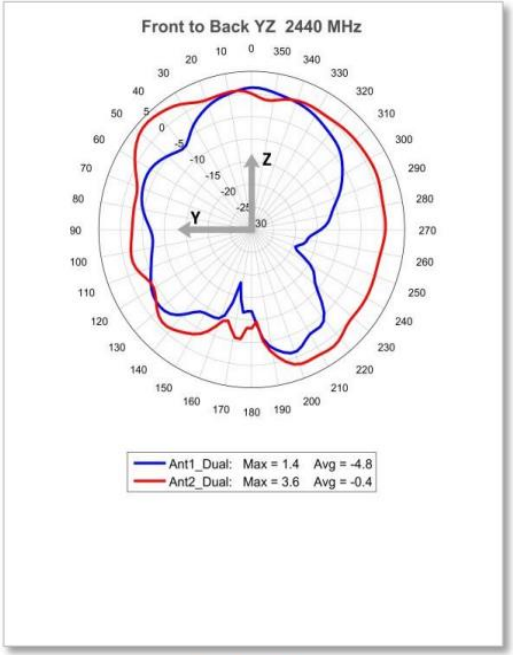
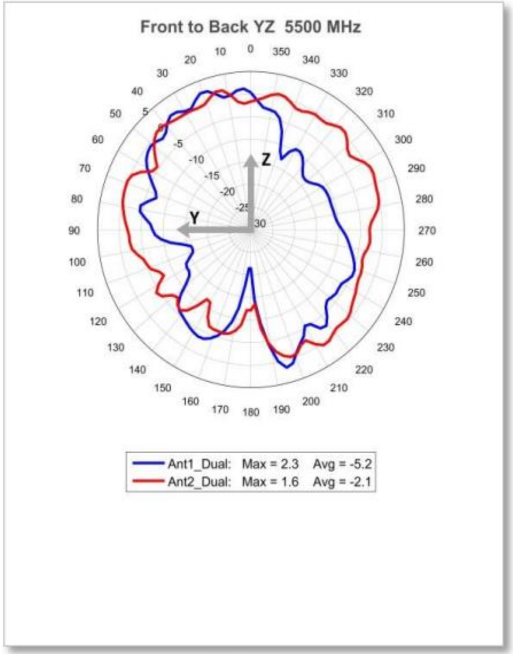
# System Coverage: Front to Back Elevation 2.44GHz & 5.5GHz




- Arrow show the max. gain direction




2.44 GHz




5.5 GHz

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# Airgain Performance summary

- Return Loss:
  Below -10dB for all antennas

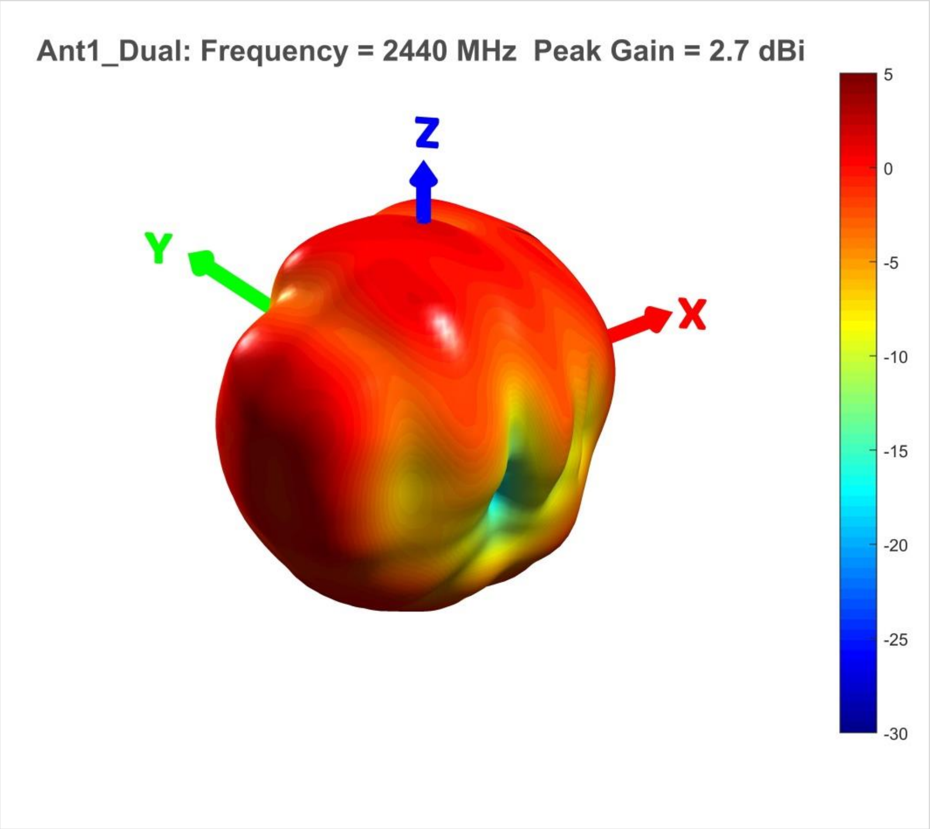
- Isolation:
  Below -30dB between dual band antennas @2.4GHz
  Below -30dB between dual band antennas @5GHz

  Below -18dB between dual band and RF4CE antennas @2.4GHz
  Below -40dB between dual band and RF4CE antennas @5GHz

- Efficiency:
  2.4GHz antennas > 60%
  5GHz antennas > 59%

# Appendix

# 3D Antenna Pattern – [Ant1_Dual at 2.44GHz]





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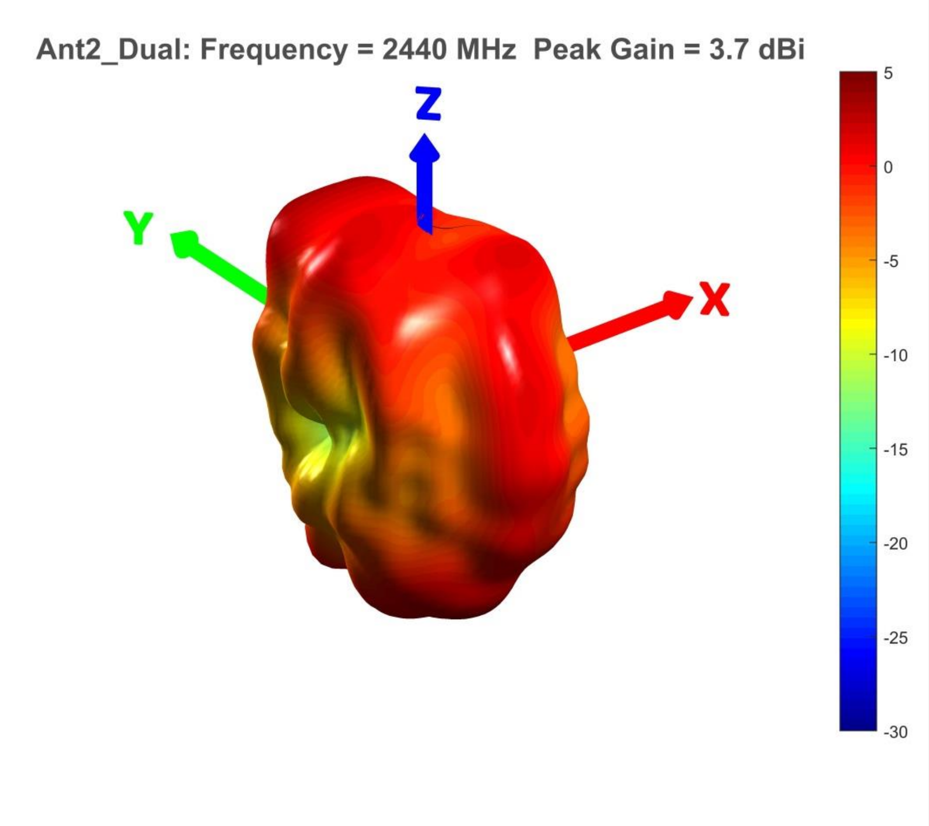
# 3D Antenna Pattern – [Ant2_Dual at 2.44GHz]





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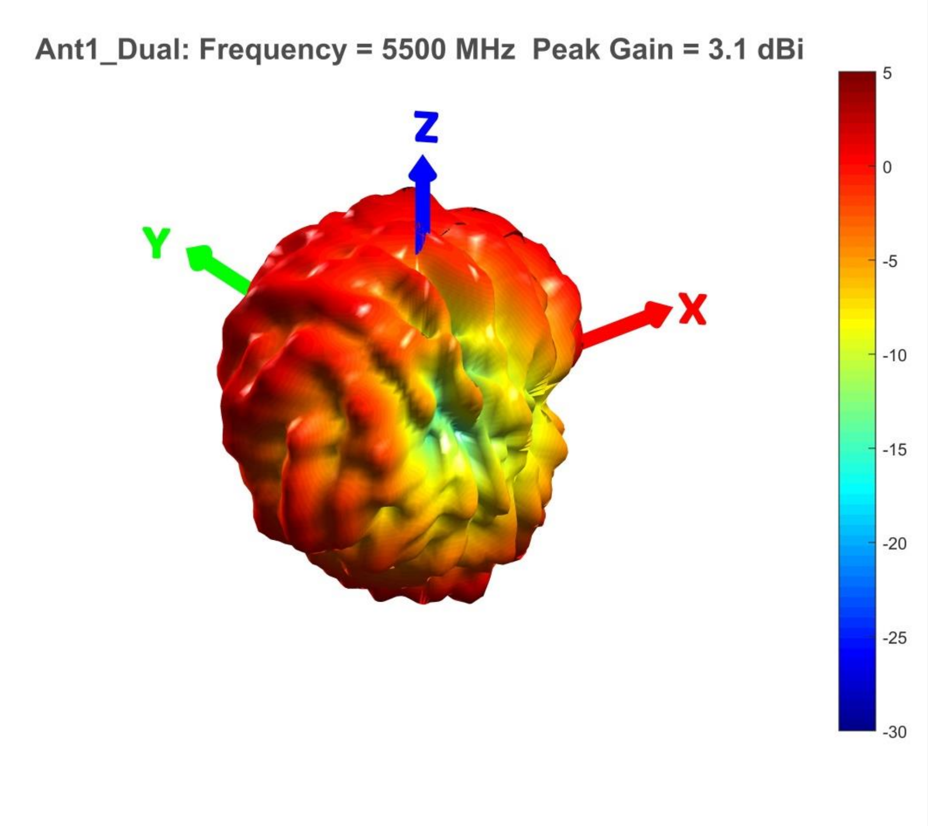
# 3D Antenna Pattern – [Ant1_Dual at 5.5GHz]





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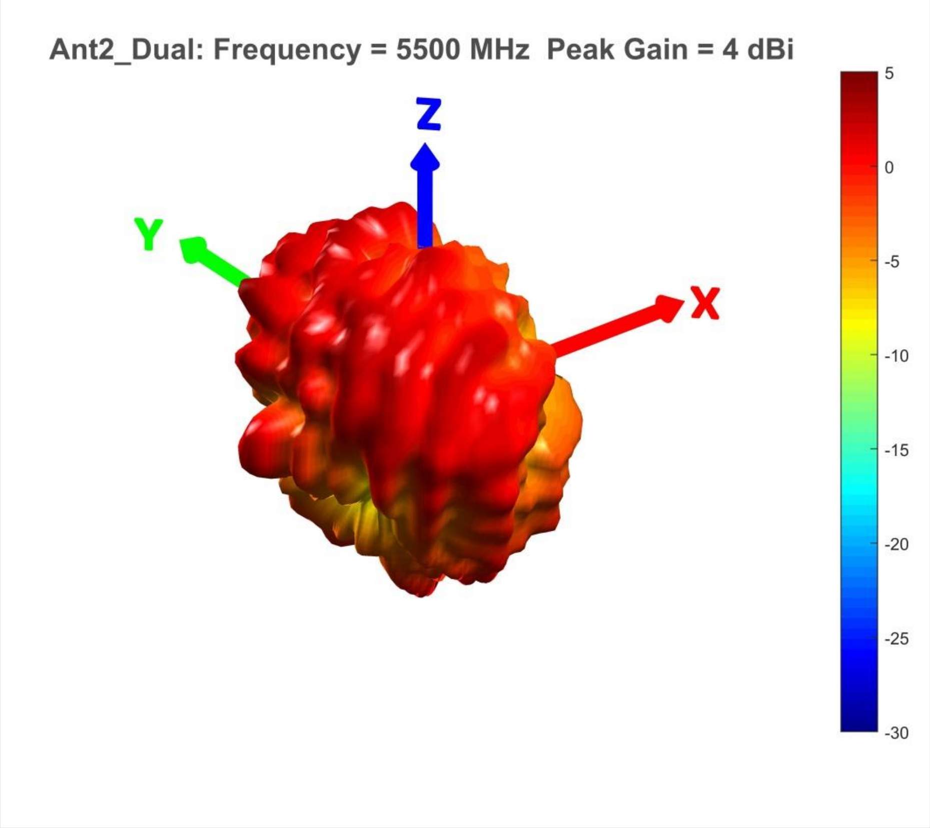
# 3D Antenna Pattern – [Ant2_Dual at 5.5GHz]







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# General Composite Gain Calculation

- The composite gain is based on FCC document 662911. Part d (ii)

d) *Unequal antenna gains, with equal transmit powers.* For antenna gains given by $G_1$, $G_2$, …, $G_N$ dBi

(i) If transmit signals are *correlated*, then

Directional gain = $10 \log[(10^{G_1/20} + 10^{G_2/20} + \ldots + 10^{G_N/20})^2 / N_{ANT}]$ dBi [Note the "20"s in the denominator of each exponent and the square of the sum of terms; the object is to combine the signal levels coherently.]

(ii) If all transmit signals are *completely uncorrelated*, then

Directional gain = $10 \log[(10^{G_1/10} + 10^{G_2/10} + \ldots + 10^{G_N/10})/N_{ANT}]$ dBi

**Reference:** FCC document, "Emissions Testing of Transmitters with Multiple Outputs in the Same Band", 662911 D01 Multiple Transmitter Output v02r01

# Phase Correlated Gain

Phase Correlated Gain is calculated as follows:

$$\text{Gain} = 10\log[|(E_1+E_2+\ldots E_N)|^2 / N_{ant}]\ \text{dBi}$$

Where $E_N$ is the *normalized* complex far-field value from the $N_{th}$ antenna, that is:
$E_N$ = (Real part of $E_N$) + j (Imaginary part of $E_N$) = $E_{N, Re} + j\, E_{N, Im}$.

Then

$$\text{Gain} = 10\log[\,|\,(E_{1,Re} + E_{2,Re} + \ldots E_{N,Re}) + j\,(E_{1,im} + E_{2,Im} + \ldots E_{N,Im})\,|^2 / N_{ant}]\ \text{dBi}$$
$$= 10\log[\,(E_{1,Re} + E_{2,Re} + \ldots E_{N,Re})^2 + (E_{1,im} + E_{2,Im} + \ldots E_{N,Im})^2\,) / N_{ant}]\ \text{dBi}$$



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# Correlated Gain For Cross-Polarized Antennas

- Composite gain is based on FCC document 662911 (previous slide)
- Calculate correlated composite gain for vertically polarized antennas Gv
- Calculate correlated composite gain for horizontally polarized antennas Gh
- Calculated total correlated gain as sum of two polarizations:

  Gt=10*log10( {[10^(Gv1/20)+10^(Gv2/20)+….+10^(GvN/20)]^2 …
  + [10^(Gh1/20)+10^(Gh2/20)+….+10^(GhN/20)]^2}/Nant)

**Reference:**

662911 D01 Multiple Transmitter Output v02r01
662911 D02 MIMO with Cross-Polarized Antenna

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# Correlated Gain For Triple-Polarized Antenna Systems

- Calculate correlated composite gain for vertically polarized antennas Gv
- Calculate correlated composite gain for X-oriented horizontally polarized antennas Ghx
- Calculate correlated composite gain for Y-oriented horizontally polarized antennas Ghy
- Calculated total gain as the uncorrelated sum of three polarizations:

Gt=10*log10( {[10^(Gv1/20)+10^(Gv2/20)+….+10^(GvN/20)]^2 …
+ [10^(Ghx/20)+10^(Ghx/20)+….+10^(Ghx/20)]^2 …
+ [10^(Ghy/20)+10^(Ghy/20)+….+10^(Ghy/20)]^2}/$N_{ant}$)

**Reference:**

662911 D01 Multiple Transmitter Output v02r01 – F.2.c.ii
662911 D02 MIMO with Cross-Polarized Antenna

*F.2.c.ii*

*Multiple antennas, each of which has one of two (or three) polarizations that are orthogonal to one another (i.e., cross polarized). (If three polarizations are used, all three polarizations must be mutually orthogonal.) The total gain—including array gain—is computed separately for each of the two (or three) polarizations using the procedures presented in this document. The highest of the total gains shall apply.*