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|  <b>CALEARO</b> <sup>®</sup> <small>antenne</small> | <b>TECHNICAL REPORT</b> | N° C201006fin1 | Rev. |
|                                                                                                                                    |                         | Page 1 of 23   |      |
| Title: WiFi/TPMS Bluetooth antenna performancefor McLaren P16 RHD                                                                  |                         |                |      |
| Ref.:                                                                                                                              |                         |                |      |

WiFi/TPMS Bluetooth antenna performance  
for McLaren P16 RHD  
Wk 39/20

| N° Rev. | Description |
|---------|-------------|
|         |             |

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## 1 PURPOSE TOC

Purpose of this report is to describe the directivity performance of the WiFi and TPMS bluetooth antennas installed on the McLaren P16.

Return loss of the two LTE antennas will be shown too.

The antennas have been characterized at the Calearo far field facilities.

## 2 APPLICATION FIELD TOC

VERIFICATION. This report can be inserted in the project P1804 - McLaren P16 antennas

## 3 REFERENCE TOC

[1 ] MP.147 Near Field measurements Calearo.

[2 ] MP.027 Electrical measurements of radio amplifiers Calearo.

## 4 D.U.T. TOC

The antenna used for WiFi and Bluetooth functionalities, together with its associated technical specifications, is illustrated below.

RoW cod. 16MA396CP (Calearo cod. 7750132)



Frequency range

- BT: 2400 - 2483.5 MHz
- WiFi 2.4 GHz: 2401 - 2495 MHz
- WiFi 5 GHz: 5170 - 5850 MHz

Output Impedance

- $Z = 50 \Omega$

ANT GAIN(Max)

- BT: 1dBi

Dimension

- 56.3 x 20 x 5.3 mm

Two antennas used for WiFi and BT connection are positioned at the end of central dashboard, under the windshield border and the wipers mounting region.

Two more antennas are placed inside the P16 vehicle for the bluetooth TPMS system. One of them, used by front wheels, is assembled inside the luggage bin at the front of the vehicle, while the other is positioned behind the right seat, hidden under the interior, and is used by the rear wheels.

During this test session, near field and return loss measurements have been performed on only one WiFi antenna by connecting to the associated exit of the unit placed in the footwell area (pink connector), therefore in this case a cable effect must be considered. On the other hand, just the TPMS rear antenna was measured inside the near field facility directly to its connector, while the return loss curves were taken on both TPMS antennas.

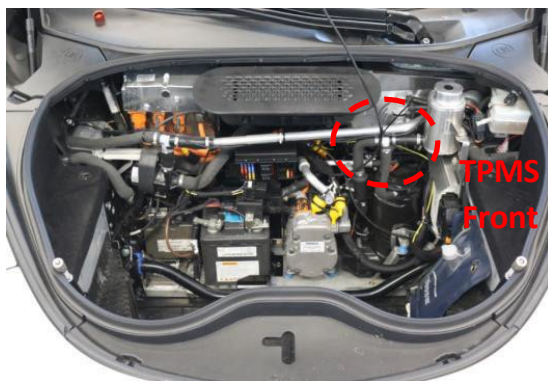
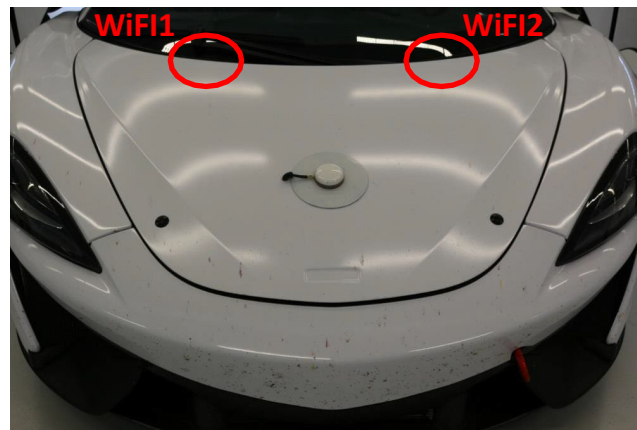


**Figure 4.1** Antennas mounting position, Wifi (Top) and TPMS Bluetooth (Bottom)

In this document the return loss curves of the two LTE antennas installed under the front wheels fenders were also included.

|          |                    |     |
|----------|--------------------|-----|
| <b>5</b> | <b>RETURN LOSS</b> | TOC |
|----------|--------------------|-----|

Return Loss of the antennas have been measured within the bands of interest: LTE, Bluetooth and WiFi. The results are displayed in terms of VSWR.

### Measurement Setup



### Instruments Used

| Instrument       | Model                                             | Calearo Code |
|------------------|---------------------------------------------------|--------------|
| Network Analyzer | R & S ZNB 8<br>VECTOR ANALYZER<br>9 KHz - 8.5 GHz | 5274         |

### Instruments Setup

| Instrument       | Parameter       | Value                                                   |
|------------------|-----------------|---------------------------------------------------------|
| Network Analyzer | Frequency range | [2000-6500] MHz - 1501 pts<br>[500-2800] MHz - 1151 pts |
|                  | Power output    | -15 dBm                                                 |
|                  | IFBW            | 1 KHz                                                   |

Test site details – Calearo

Via Bacchiglione, 49  
36033 Isola Vicentina (VI)  
Italy

Calibration and calibration date

Startlab standard method with a wideband (2200-6000MHz) reference antenna (SMC2200)

Calibration and test date - 10/08/2017

Test engineer - Enrico Toniolo

|                        |     |
|------------------------|-----|
| <b>5.1 LTE RESULTS</b> | TOC |
|------------------------|-----|

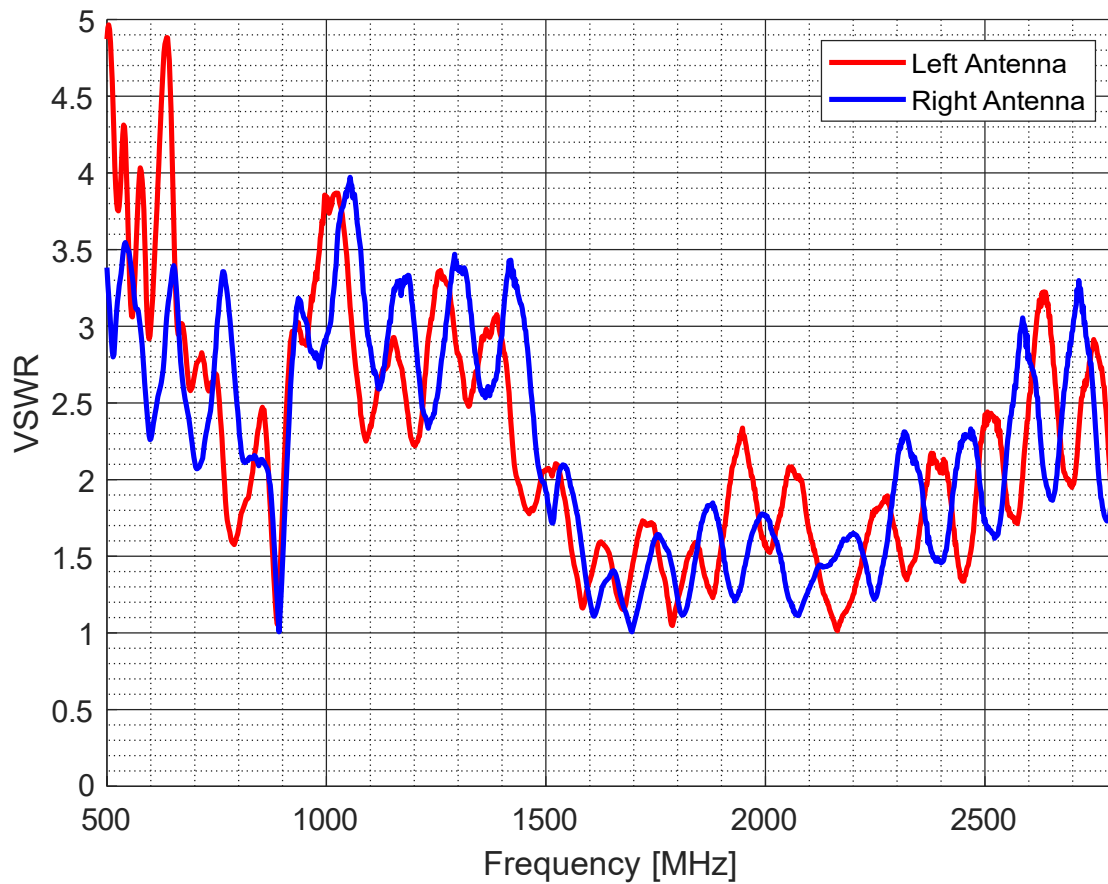


**Figure 5.1** VSWR of the two LTE antennas

|                         |     |
|-------------------------|-----|
| <b>5.2 WIFI RESULTS</b> | TOC |
|-------------------------|-----|

### 2.4 GHz - BT and WiFi lower band

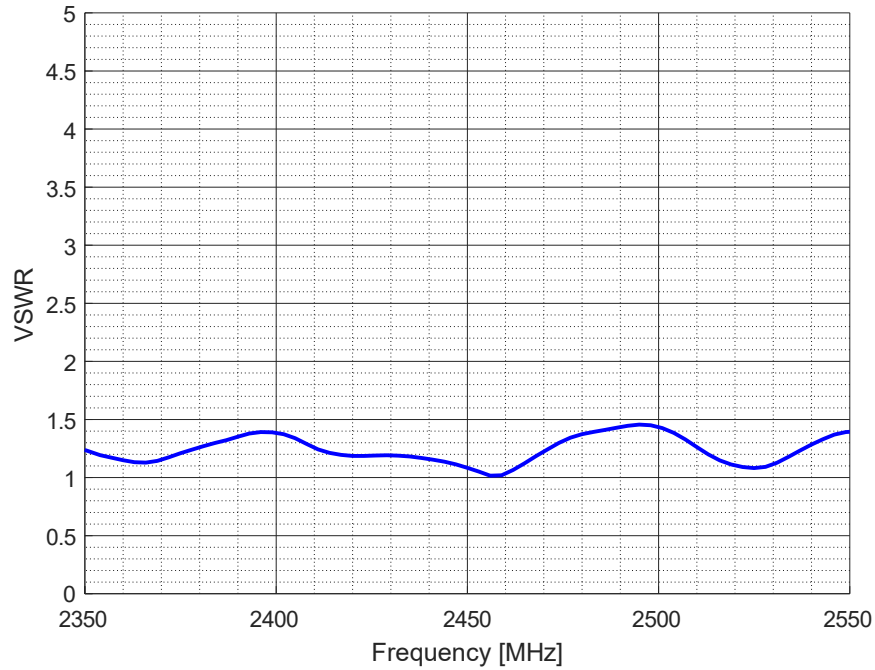


**Figure 5.2** VSWR of the WiFi antenna within the 2.4 GHz band

### 5 GHz - WiFi higher band

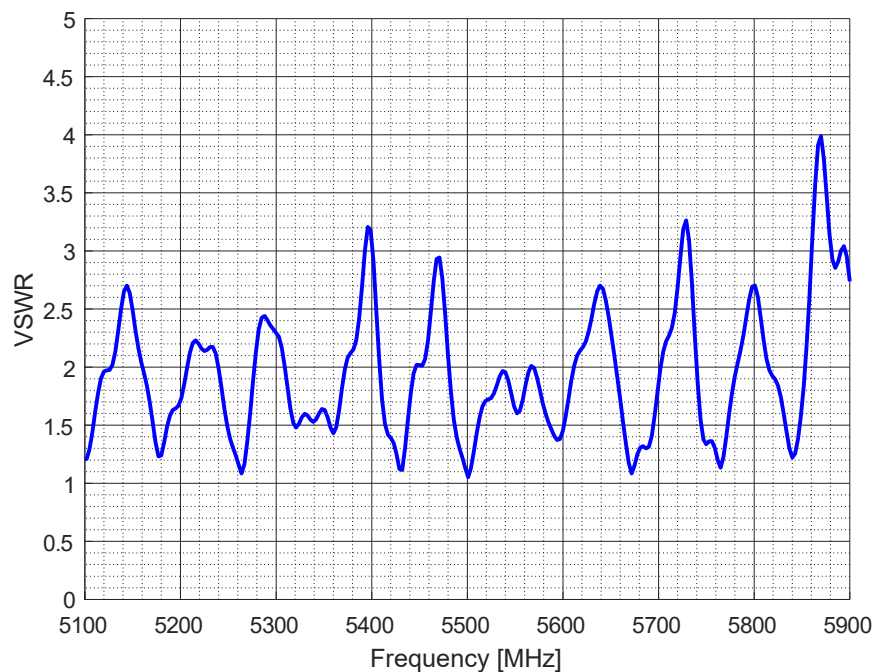


**Figure 5.3** VSWR of the WiFi antenna within the 5 GHz band

|                            |     |
|----------------------------|-----|
| <b>5.3 TPMS BT RESULTS</b> | TOC |
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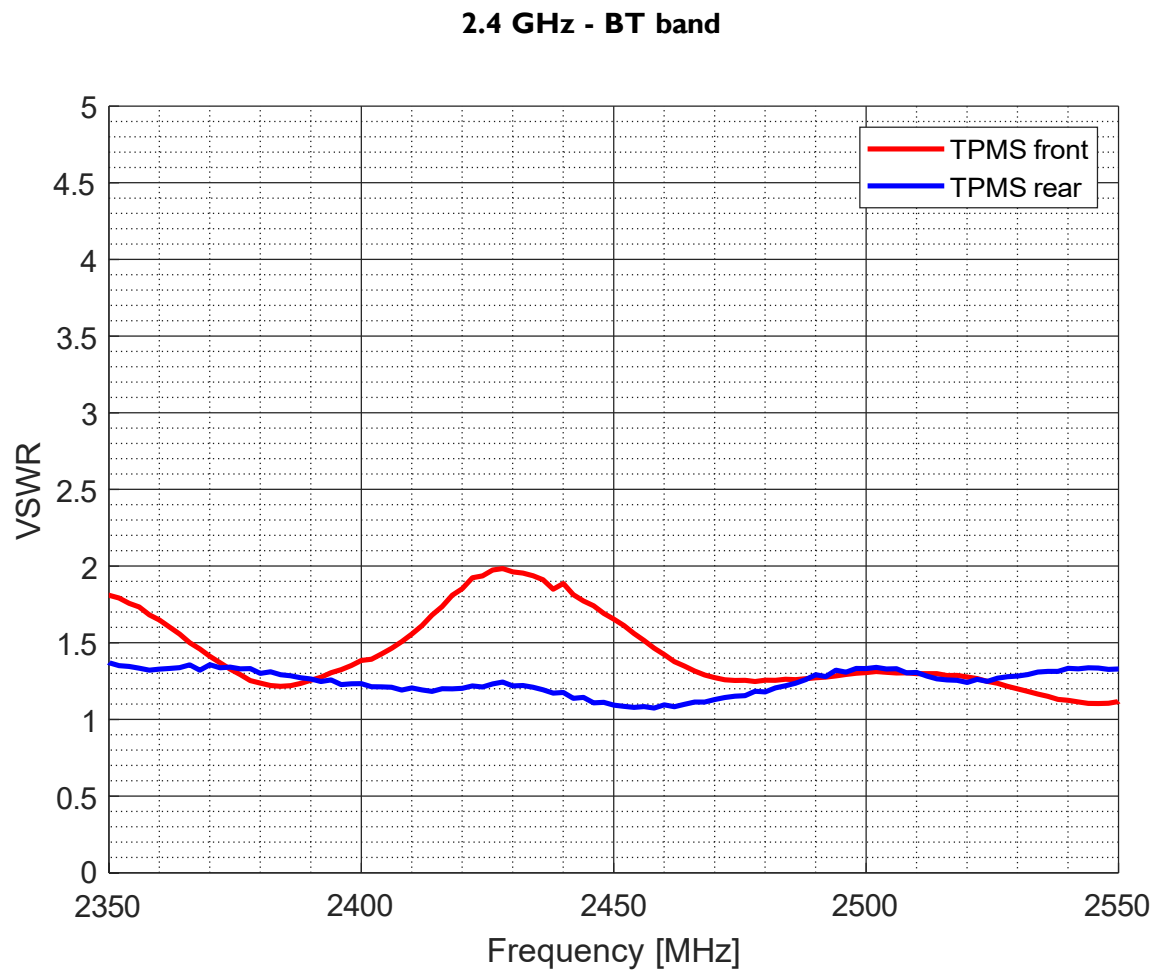


**Figure 5.4** VSWR of the two TPMS antenna within the BT 2.4 GHz band

|          |                                     |     |
|----------|-------------------------------------|-----|
| <b>6</b> | <b>NEAR FIELD RADIATION PATTERN</b> | TOC |
|----------|-------------------------------------|-----|

|            |                          |     |
|------------|--------------------------|-----|
| <b>6.1</b> | <b>MEASUREMENT SETUP</b> | TOC |
|------------|--------------------------|-----|

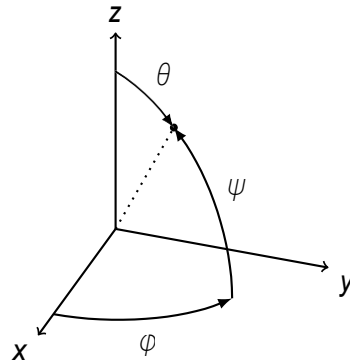


**Figure 6.1** Satimo Near-Field Dome SG 3000F, external and internal view.

| Band           | Start<br>MHz | Stop<br>MHz | Points | IFBW<br>Hz | AVG<br>points | PW<br>dBm | Probe(s)<br>types |
|----------------|--------------|-------------|--------|------------|---------------|-----------|-------------------|
| <b>TPMS BT</b> | 2400         | 2495        | 20     | 5000       | 3             | -10       | HF                |
| <b>WiFi</b>    | 2350         | 6000        | 35     | 5000       | 3             | -10       | HF                |

|                                                                                                                       |                         |                |      |
|-----------------------------------------------------------------------------------------------------------------------|-------------------------|----------------|------|
|  <div>antenne<br/><b>CALEARO</b></div> | <b>TECHNICAL REPORT</b> | N° C201006fin1 | Rev. |
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| Title: WiFi/TPMS Bluetooth antenna performancefor McLaren P16 RHD                                                     |                         |                |      |
| Ref.:                                                                                                                 |                         |                |      |

In order to make easier the following graphs reading, it's necessary to consider the reference system illustrated below. Where  $\xi$  (sometimes indicated with  $\psi$ ) is the elevation angle and  $\varphi$  is the azimuthal angle.



Elevation  $\xi = 90^\circ - \theta$ .

### POLAR PATTERN

$G(\varphi, \theta, f)$  is the measured linear gain magnitude in Watt.

For dB conversions:

$$G_{\text{dBi}} = 10 \log_{10} G$$

dB<sub>i</sub> = dB referred to isotropic

### LINEAR AVERAGE GAIN

$$20 \log_{10} \text{mean}_{\varphi, \theta \in [\theta_1, \theta_2]} \{G(\varphi, \theta, f)\}^{1/2}$$

### GLOBAL EXCEEDING PROBABILITY

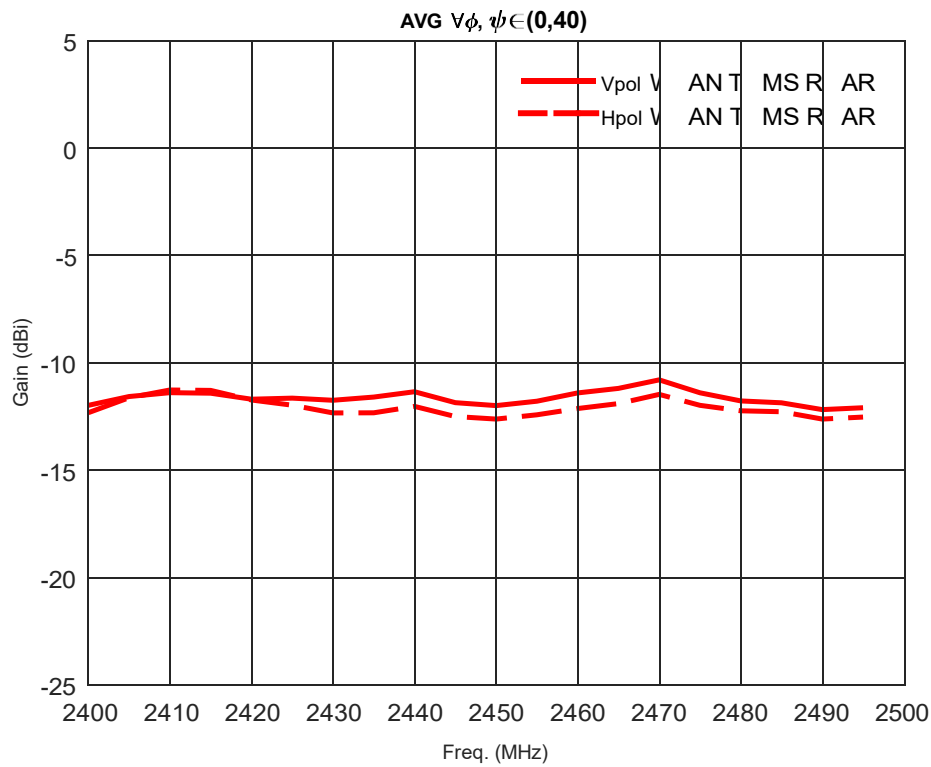
$$P[G(\varphi, f) \geq \gamma], \quad \forall \varphi, \quad \theta \in [\theta_1, \theta_2], \quad f \in [f_{\min}, f_{\max}]$$

### STANDARD DEVIATION

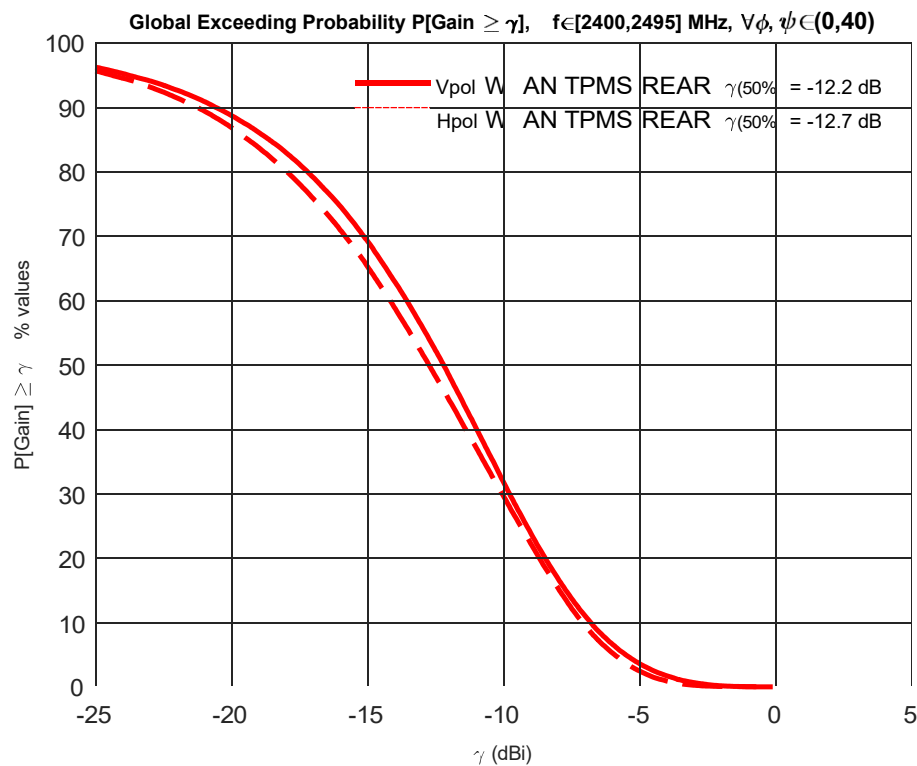
$$\text{std}_{\varphi} G_{\text{dBi}}(\varphi, \theta, f) = \frac{1}{n} \sum_{i=1}^n G_{\text{dBi}}(\varphi_i, \theta, f) - M \Big)^2 \Big)^{1/2}, \quad M = \frac{1}{n} \sum_{i=1}^n G_{\text{dBi}}(\varphi_i, \theta, f)$$

|                                    |     |
|------------------------------------|-----|
| <b>6.2 RESULTS - TPMS REAR</b>     | TOC |
| <b>6.2.1 AVG GAIN VS FREQUENCY</b> | TOC |

AVG Gain  $\forall \varphi$  vs  $f, \xi \in \{0^\circ, 40^\circ\}$

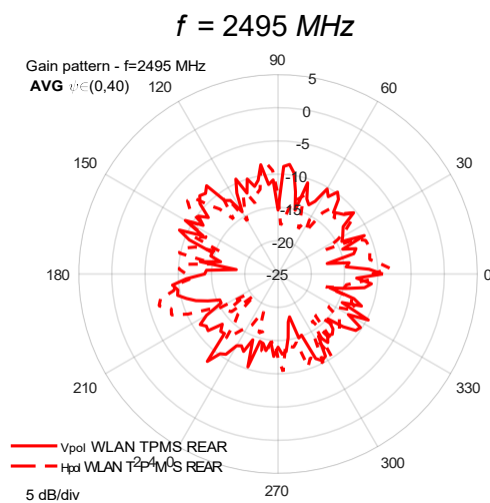
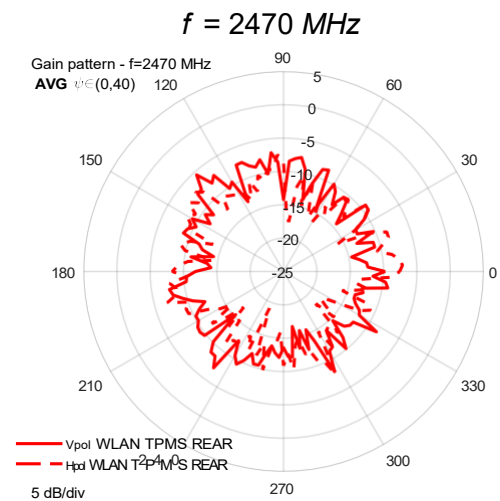
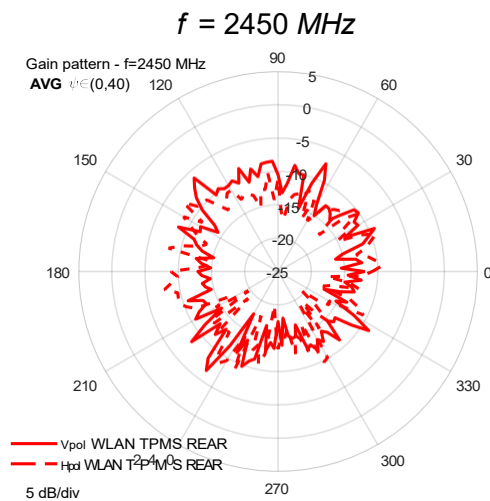
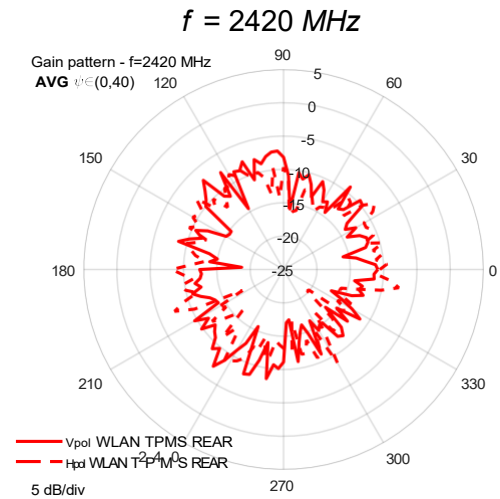
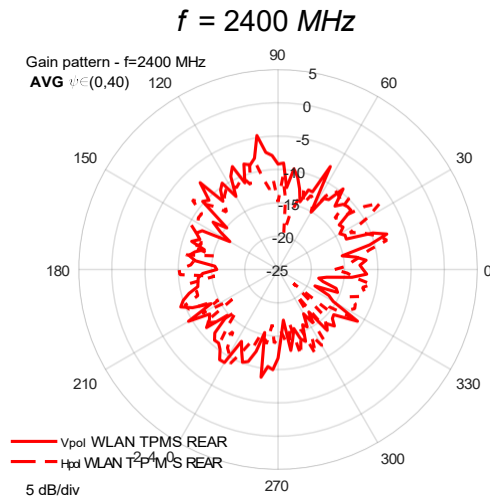


Global Exceeding Probability  $\forall \varphi$  vs  $f, \xi \in \{0^\circ, 40^\circ\}$



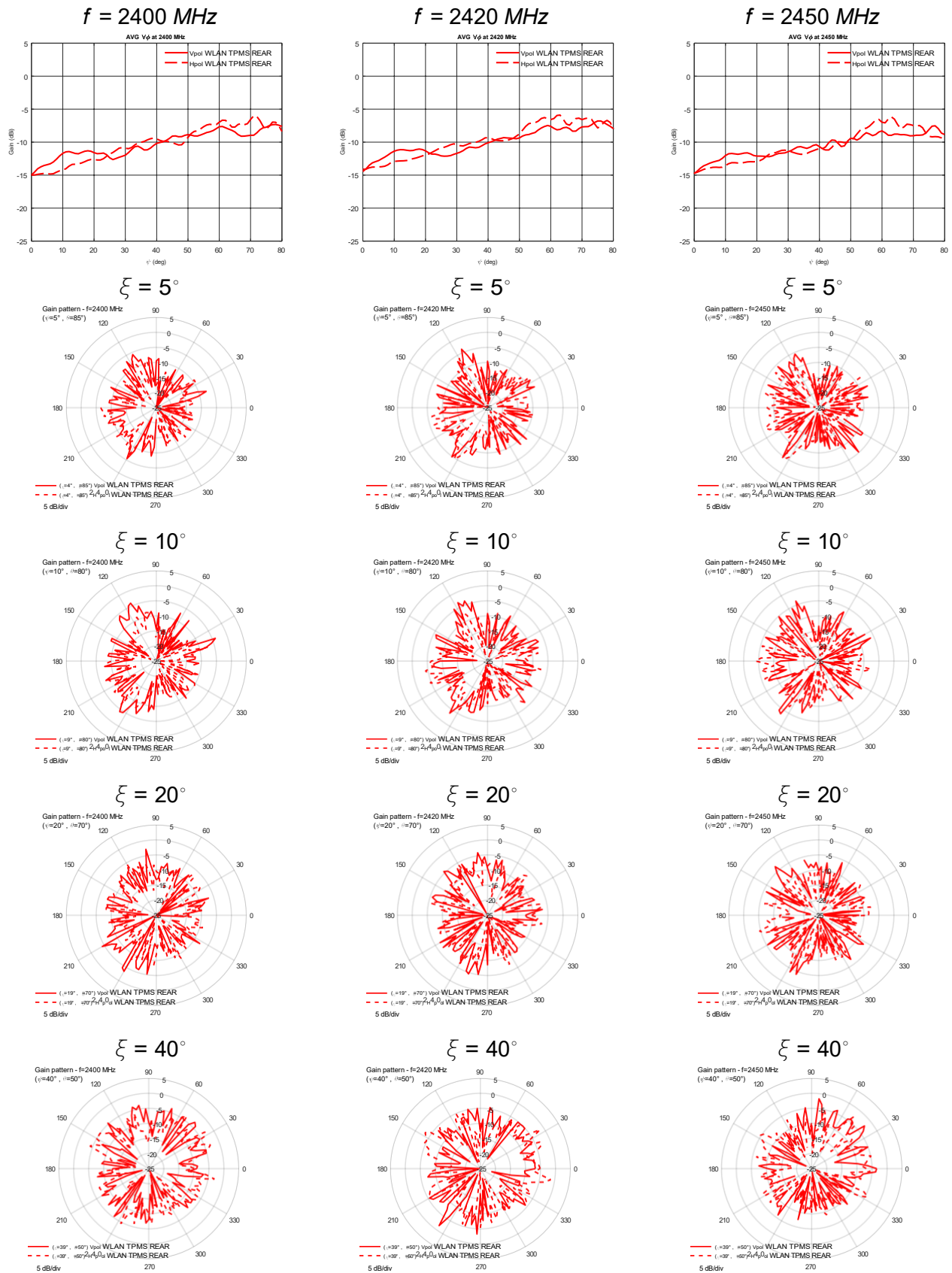
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| <b>6.2.2 AVG GAIN VS AZIMUTH</b> | TOC |
|----------------------------------|-----|

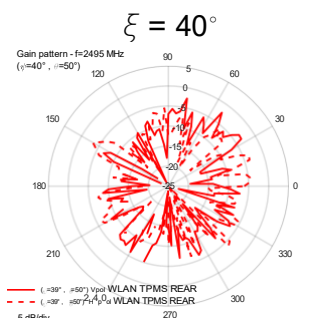
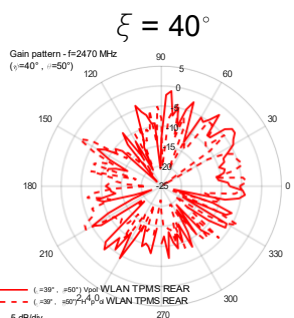
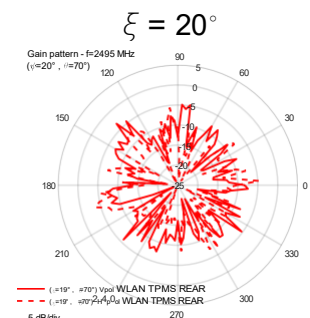
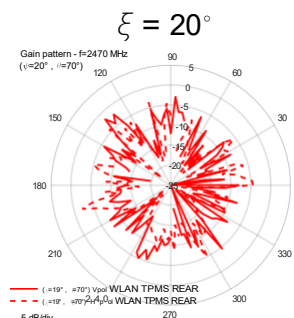
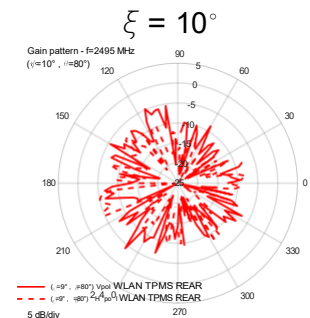
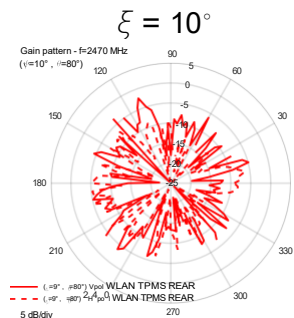
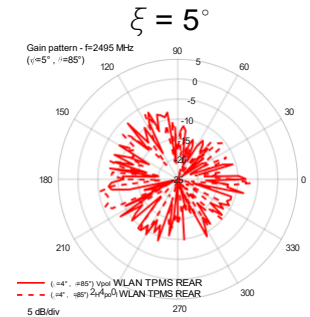
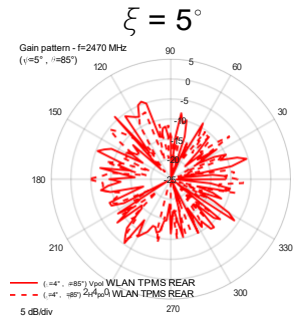
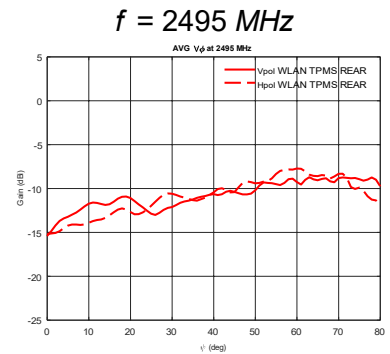
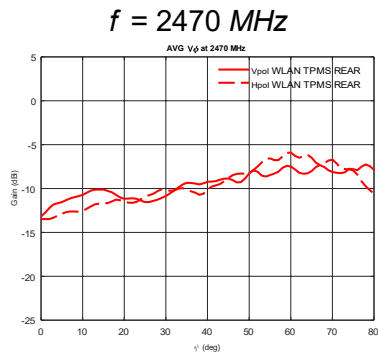
AVG Gain varying  $\varphi, \xi \in \{0^\circ, 40^\circ\}$



|                                      |     |
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| <h2>6.2.3 AVG GAIN VS ELEVATION</h2> | TOC |
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### AVG Gain $\forall \varphi$ vs $\xi$

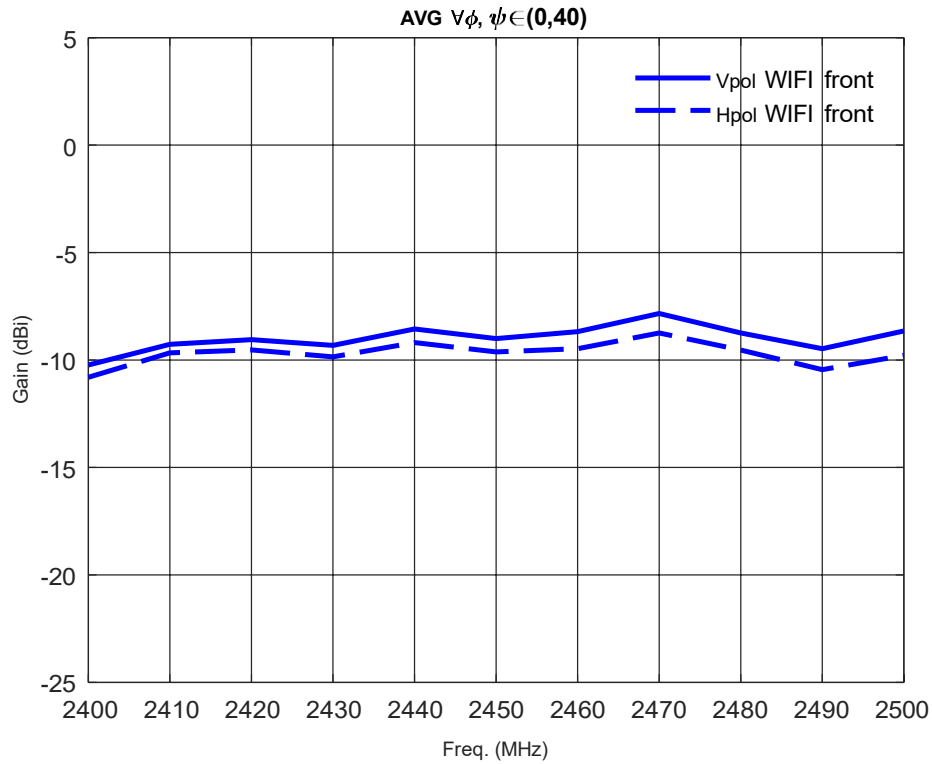




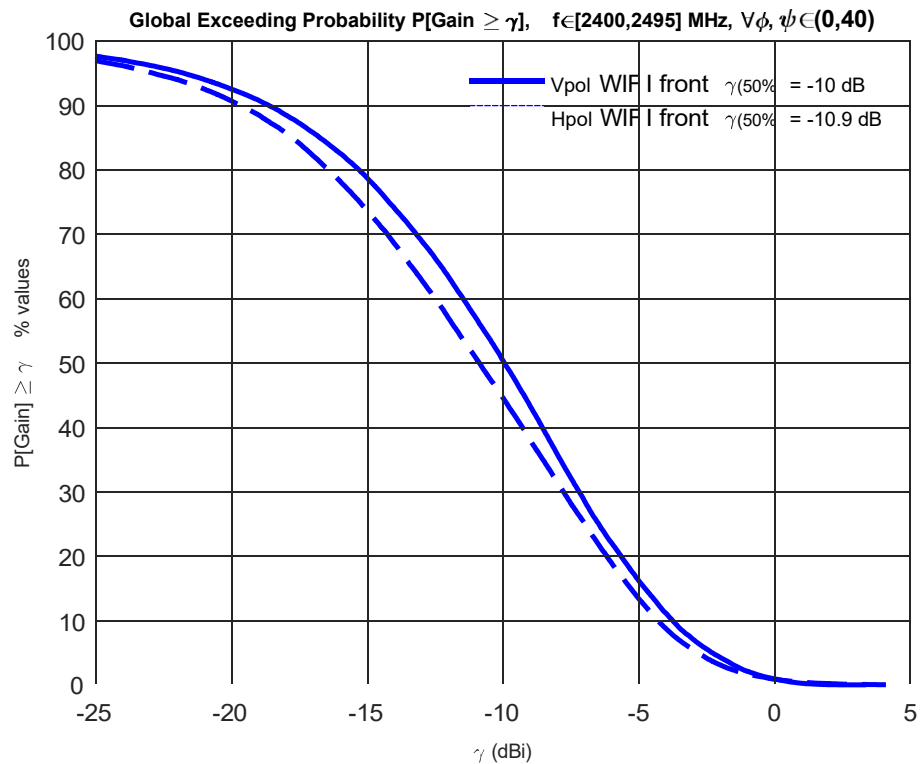
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| <b>6.3 RESULTS - WIFI 2.4 GHZ BAND</b> | TOC |
|----------------------------------------|-----|

|                                    |     |
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| <b>6.3.1 AVG GAIN VS FREQUENCY</b> | TOC |
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**AVG Gain  $\forall \varphi$  vs  $f$ ,  $\xi \in \{0^\circ, 40^\circ\}$**

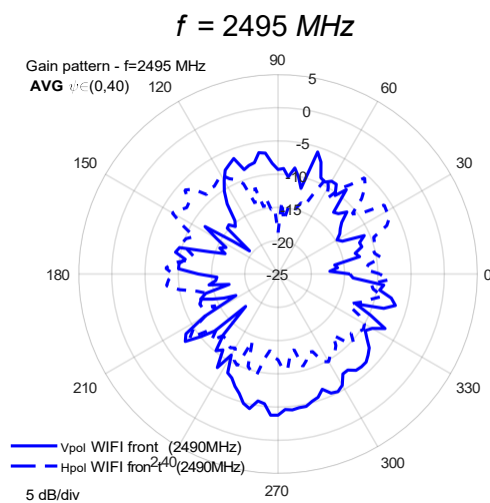
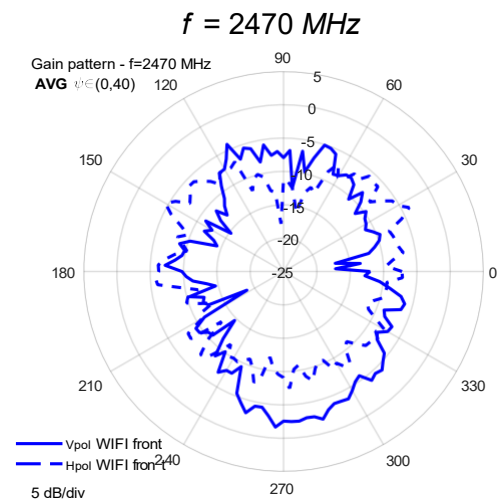
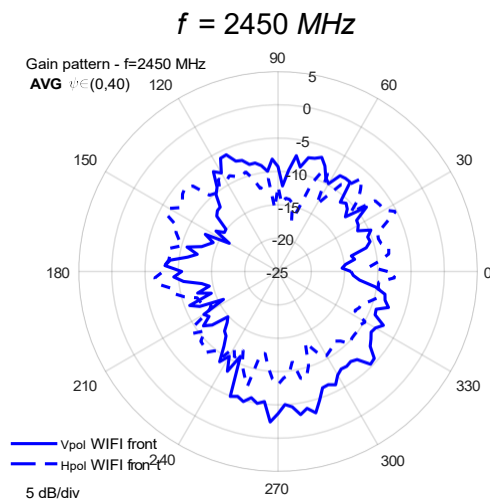
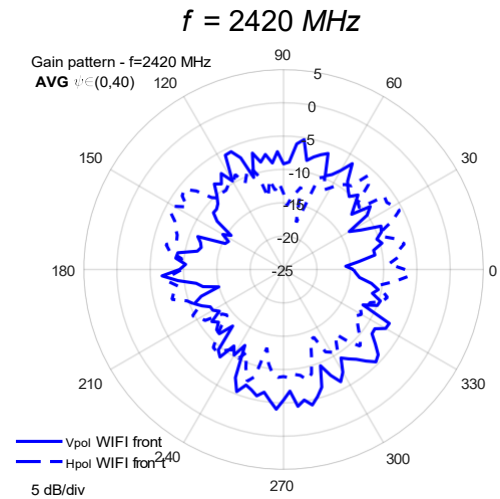
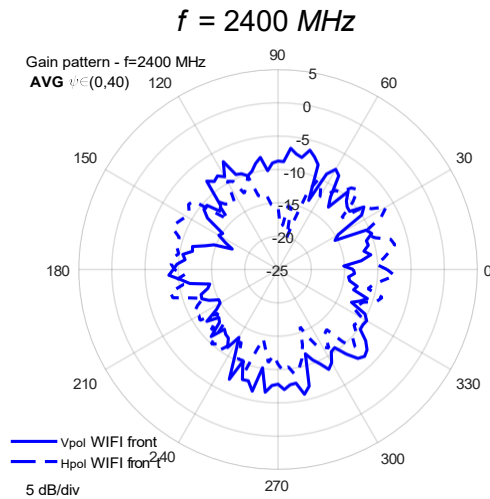


**Global Exceeding Probability  $\forall \varphi$  vs  $f$ ,  $\xi \in \{0^\circ, 40^\circ\}$**



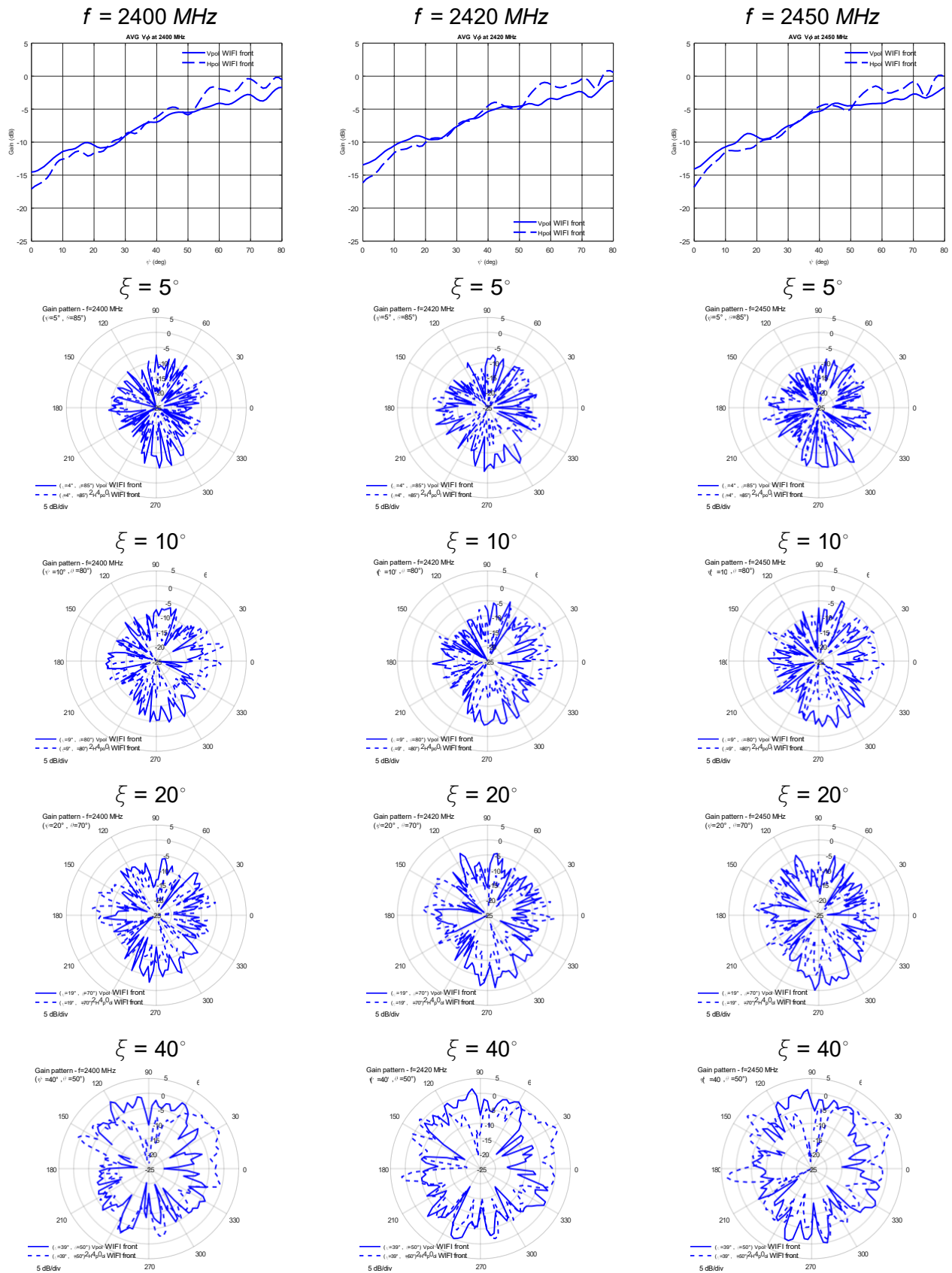
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| <b>6.3.2 AVG GAIN VS AZIMUTH</b> | TOC |
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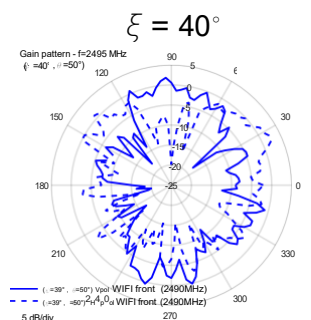
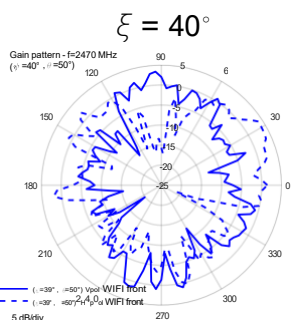
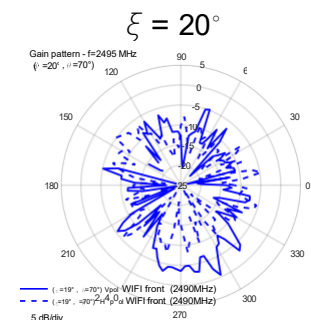
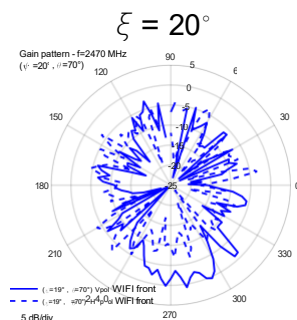
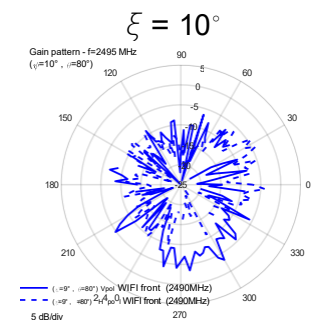
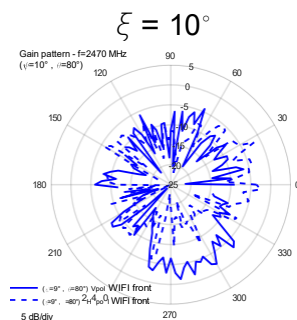
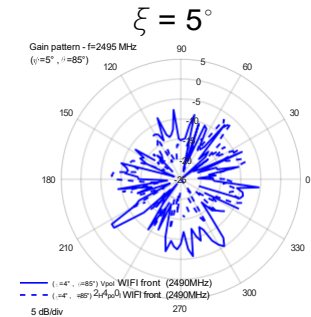
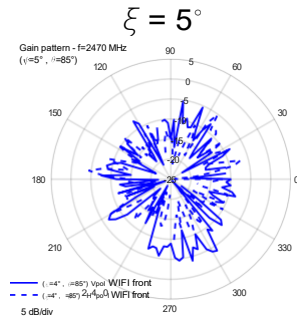
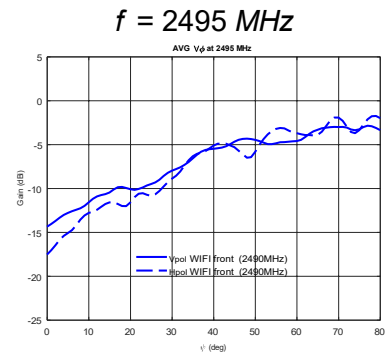
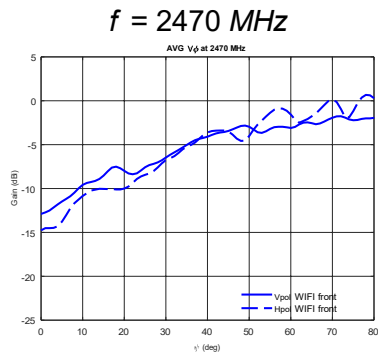
AVG Gain varying  $\varphi, \xi \in \{0^\circ, 40^\circ\}$



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| <h2>6.3.3 AVG GAIN VS ELEVATION</h2> | TOC |
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### AVG Gain $\forall \varphi$ vs $\xi$

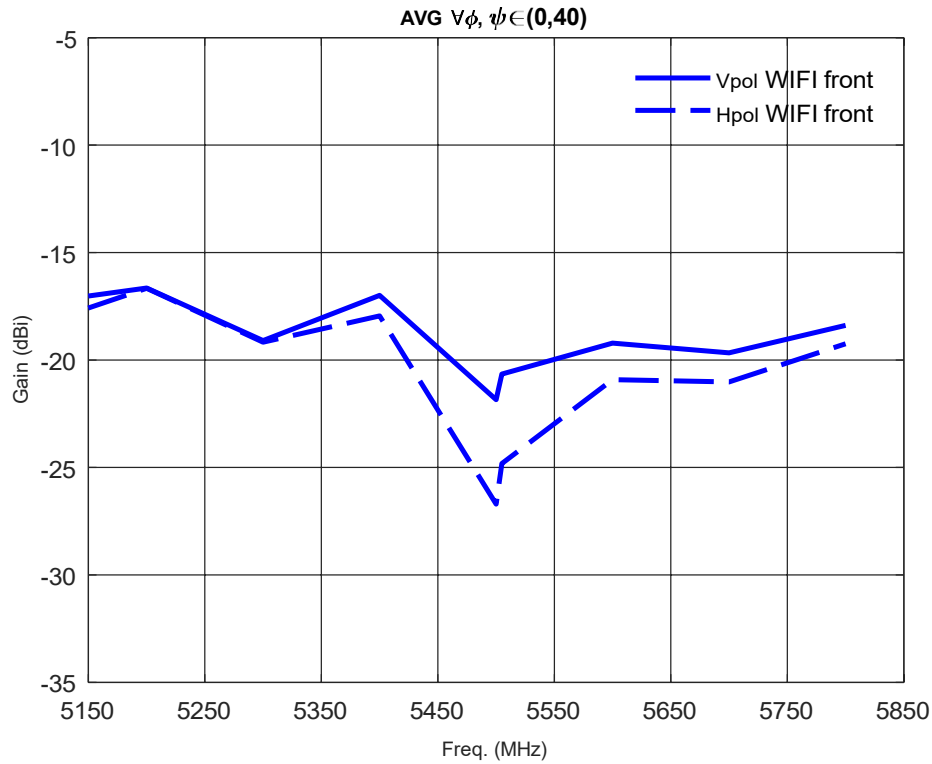




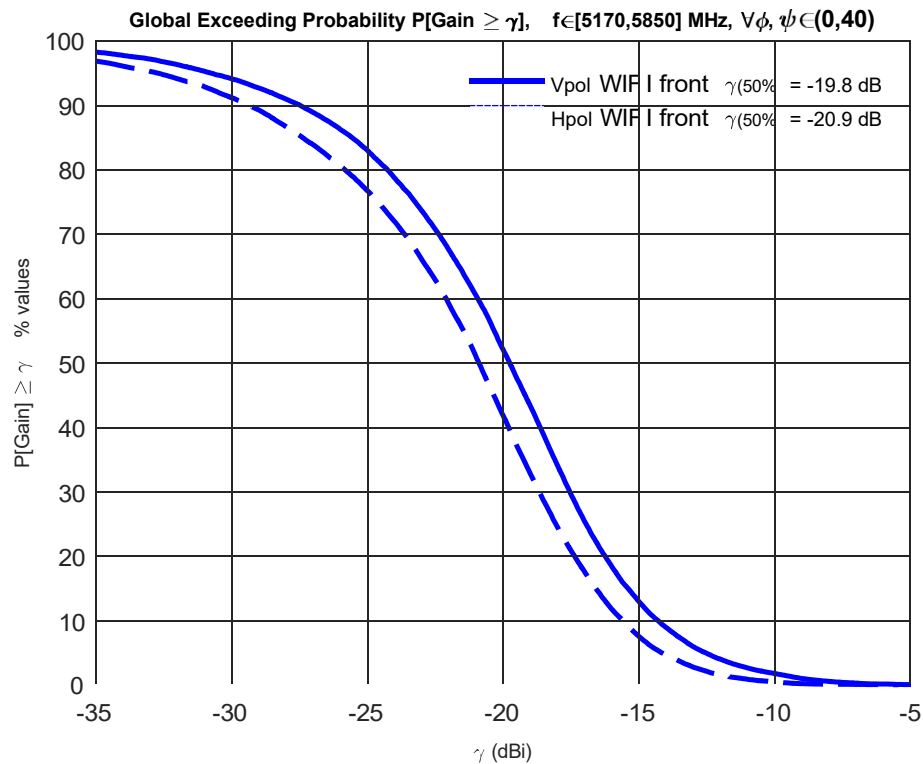
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| <b>6.4 RESULTS - WIFI 5 GHZ BAND</b> | TOC |
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|------------------------------------|-----|
| <b>6.4.1 AVG GAIN VS FREQUENCY</b> | TOC |
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**AVG Gain  $\forall \varphi$  vs  $f$ ,  $\xi \in \{0^\circ, 40^\circ\}$**

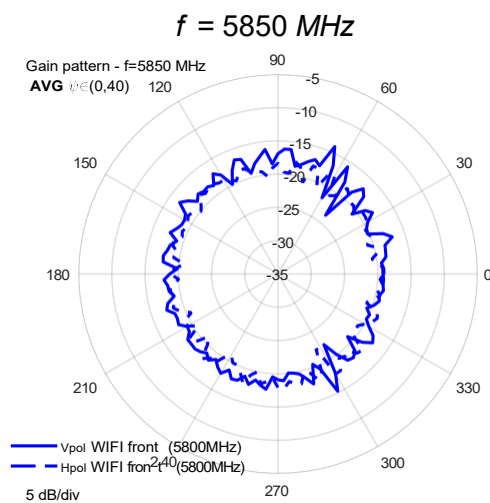
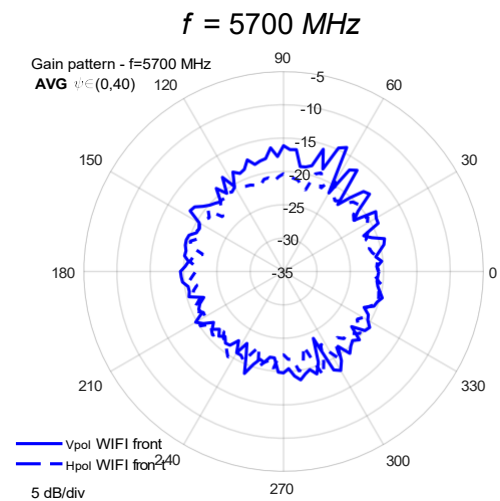
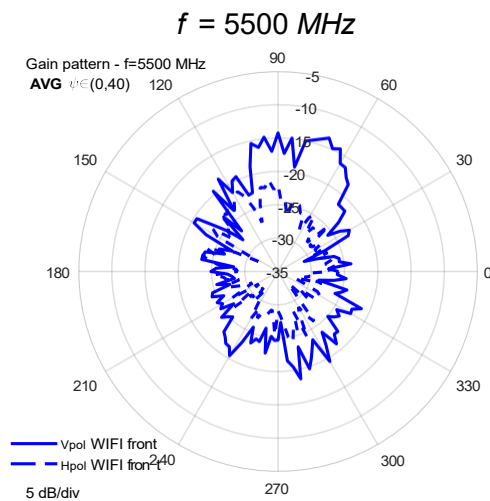
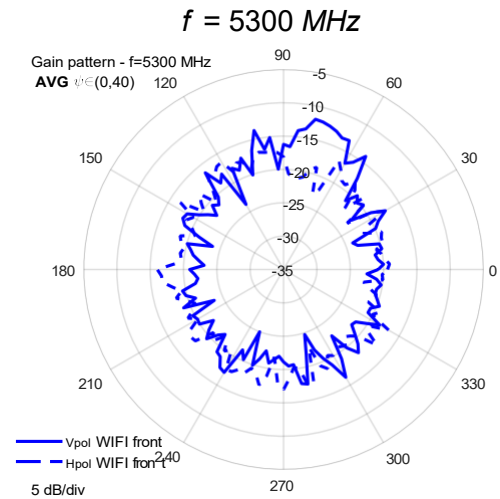
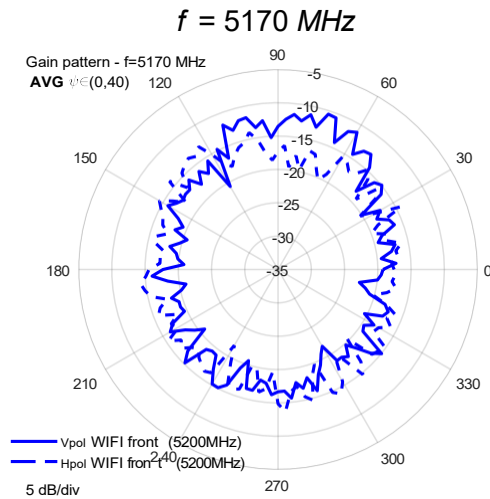


**Global Exceeding Probability  $\forall \varphi$  vs  $f$ ,  $\xi \in \{0^\circ, 40^\circ\}$**



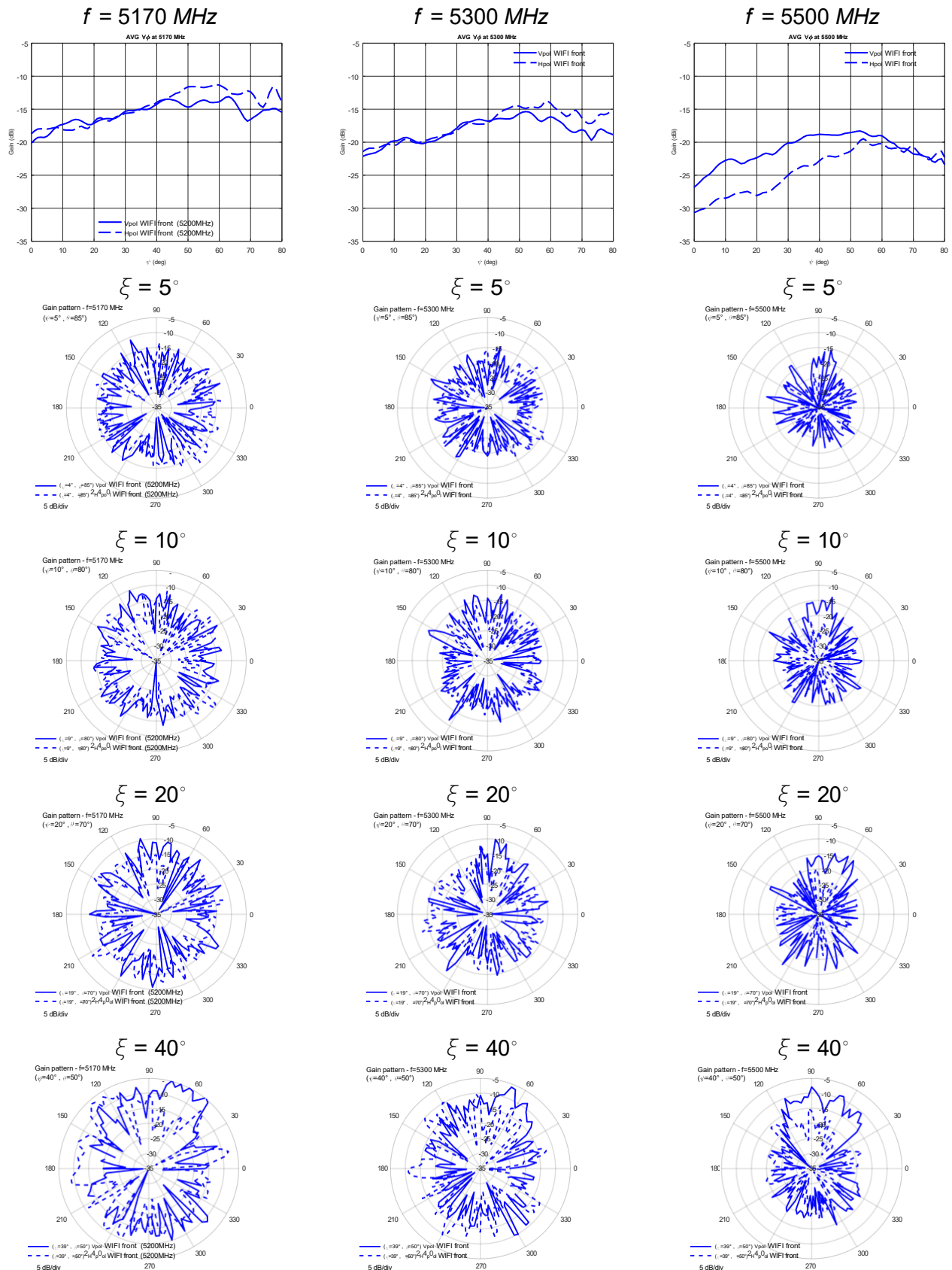
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| <b>6.4.2 AVG GAIN VS AZIMUTH</b> | TOC |
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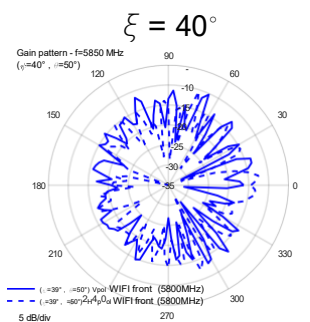
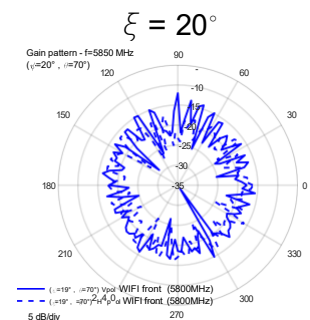
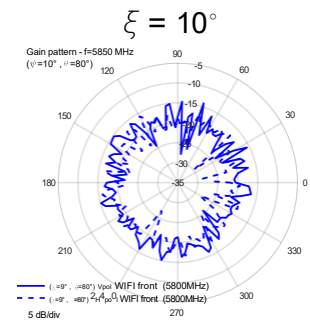
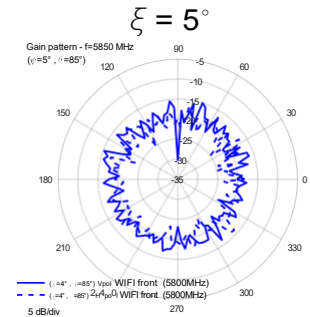
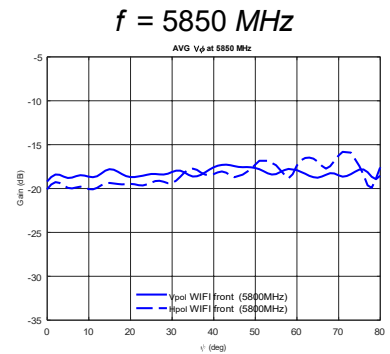
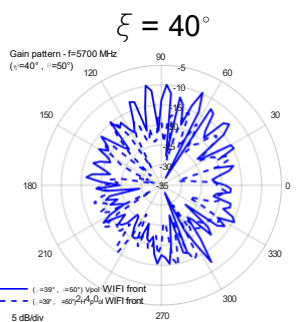
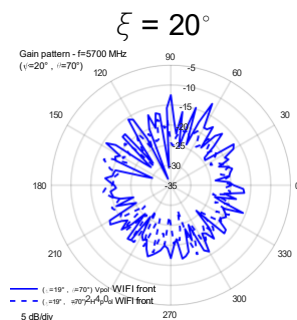
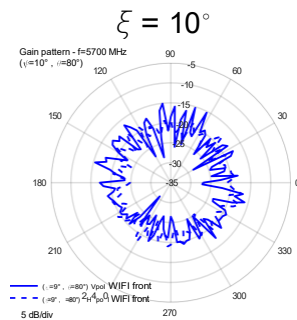
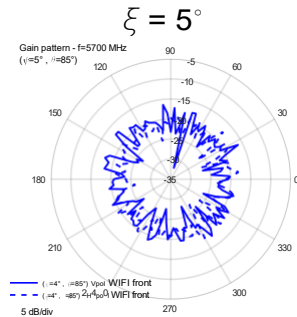
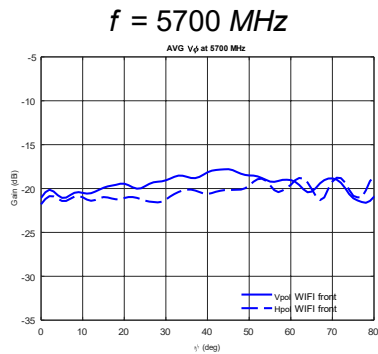
AVG Gain varying  $\varphi, \xi \in \{0^\circ, 40^\circ\}$



|                                      |     |
|--------------------------------------|-----|
| <h2>6.4.3 AVG GAIN VS ELEVATION</h2> | TOC |
|--------------------------------------|-----|

### AVG Gain $\forall \varphi$ vs $\xi$





|                                                                                                                           |                         |               |                |      |
|---------------------------------------------------------------------------------------------------------------------------|-------------------------|---------------|----------------|------|
|  <b>CALEARO</b><br><small>antenne</small> | <b>TECHNICAL REPORT</b> |               | N° C201006fin1 | Rev. |
| Title: WiFi/TPMS Bluetooth antenna performancefor McLaren P16 RHD                                                         |                         | Page 23 of 23 |                |      |
| Ref.:                                                                                                                     |                         |               |                |      |

|          |                   |     |
|----------|-------------------|-----|
| <b>7</b> | <b>CONCLUSION</b> | TOC |
|----------|-------------------|-----|

The goal of this study is to evaluate the directivity performance of WiFi and TPMS BT antennas installed inside the McLaren P16 vehicle. After performing the measurements, the following conclusions can be drawn:

- Rear TPMS Bluetooth and WiFi antennas presents a very good return loss within the 2.4 GHz band ( $VSWR < 2 : 1$ ).
- In the 5 GHz spectrum the WiFi return loss curve is not perfect due to the cable effect, that is much visible at higher frequencies. The same considerations apply also to the LTE antennas. To have a real vision of the antenna return loss, the measurements performed during Wks 40-41/2019 test session should be considered.
- Directivity performance of the rear TPMS Bluetooth is not optimal beacuse of the antenna location which is inside the cockpit and shielded by the car body. However, this does not affect the final reception performance, because in a real world usage the useful signal for the antenna comes from the rear wheels, not from the external environment.
- Average gain values of the WiFi antenna are in line with expectations for both frequency band of interest. For small elevation angles the performance is not optimal because of the car body proximity, while when the angular direction moves toward the zenith, the gain grows because the antenna is free to irradiate through the windshield.
- WiFi antenna has been measured at the footwell unit, therefore in every directivity diagram the cable loss effect is included.
- Testing only one of the two elements for each functionalities is satisfactory to have a really good vision of the overall external directivity performance.

|                                   |                                |                                         |                                    |
|-----------------------------------|--------------------------------|-----------------------------------------|------------------------------------|
| <b>Date of data:</b><br>Wks 39/20 | <b>Date:</b><br>05 · 10 · 2020 | <b>Released by:</b><br>Federico Finotto | <b>Approved by:</b><br>Ilenia Moro |
|-----------------------------------|--------------------------------|-----------------------------------------|------------------------------------|