Third Party Validation Report

Privoro Privacy Guard Radio Frequency Attenuation Validation
Testing organization: Blue Flux, a ctia Authorized Test Lab
Date of Report: June 20, 2016
Prepared by: Benjamin Wilmhoff, President

PRIVORO®

Summary Test Report

Customer Privoro, LLC

Date 20 June 2016

Table B-1 Equipment Under Test (EUT) Information	
Manufacturer	Privoro, LLC
Model	PGP3AC6SB
Serial Number(s) / ESN(s) / IMEI(s)	OB10FC19

Bluflux Inc. - 609 S. Taylor Ave. - Louisville, Co. 80027 - www.bluflux.com 720-336-9840

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1. General Information

1.1. Revision History

Version number	Author	Date	Description
V1	B Wilmhoff	6-16-16	Original
V2	B Wilmhoff	6-17-16	Updated contact information; completed Appendix A; corrected errata in equations
V3	B Wilmhoff	6-20-16	Fig 1 – iPhone 6, not 6s; Fig 4 – used data from wrong equation that was corrected in v2

1.2. Test Report Authorization

This report applies only to the item(s) tested and shall not be reproduced in part or in full without the consent of Bluflux.

Prepared By: Benjamin Wilmhoff

Title: President

Signature:

Date: 6-20-2016

1.3. Client Information

Client Name	Privoro, LLC
Address	3100 W. Ray Road Suite 201 Chandler, AZ 85226

1.4. Responsible Testing Laboratory

Company	Bluflux
Address	609 S. Taylor Ave. – Suite E, Louisville Co. 80027
Phone	720-336-9840

2. Reference Documents

Document Number	**Description**
BluFlux Proposal 1603-301; 1604-342; 1605-494	Proposals for various test campaigns
CTIA Test Plan for Mobile Device Over-the-Air (OTA) Performance, v3.5.2	Current document which standardizes the power output (TRP) and sensitivity (TIS) measurements of cellular devices

3. Abbreviations

TRP	Total Radiated Power	OTA	Over the Air
FS	Freespace	TIS	Total Isotropic Sensitivity
DUT	Device Under Test		

4. Equipment Under Test (EUT)

The equipment under test is found in **Figure 1**. A custom transmitter unit (a) is used to assess shielding effectiveness as a proxy for an actual mobile device inside the Privoro case and Privacy Guard - (b) and (c). A standard cellular base station emulator would lack the dynamic range and sensitivity necessary to perform standard TRP (Total Radiated Power) tests per the CTIA Over-the-Air (OTA) Test Plan for Mobile Devices, so a custom transmitter which outputs a high power CW tone at tunable center frequencies is used with a spectrum analyzer to measure the bare and shielded transmitter power output.

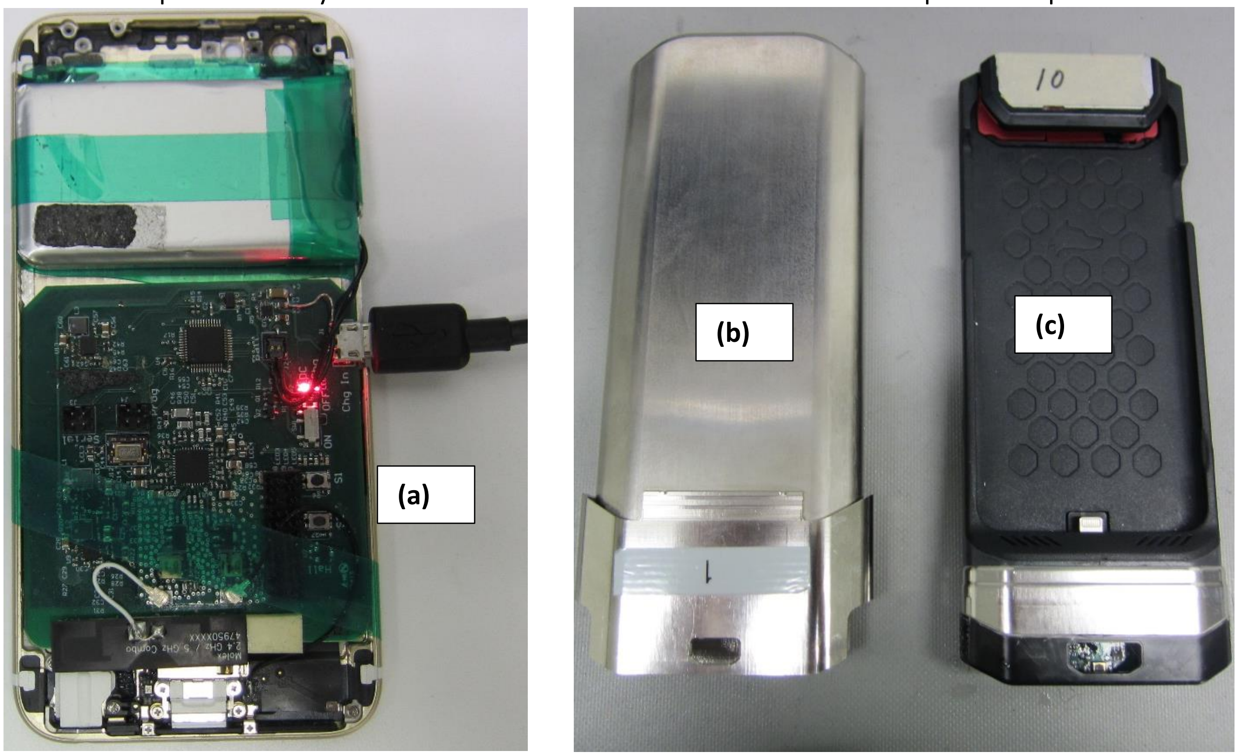


Figure 1: Privoro custom transmitter built into an iPhone 6 chassis (a); Privoro privacy guard sleeve (b); Privoro electronic case without Privacy Guard (c)

5. Test Equipment and Method

This section describes the test equipment and method as well as the data calibration and reporting methodology.

5.1. Test Equipment

The test plan designed here is NOT specified by, controlled by or certified by any other accrediting agency, including CTIA, A2LA or ISO. It is a custom test plan using best practices inside a certified facility.

- ISO-17025 accreditation through A2LA; certificate number 3795.01
- CTIA certificate number 20151130-00

Testing was performed in a 3m x 3m x 3m shielded anechoic chamber with shielding effectiveness greater than 100 dB. The facility is an ISO-17025 calibration laboratory for certified testing per CTIA Test Plan 3.5.2, “Mobile Device Over-the-Air (OTA) Performance.”

The chamber is ETS-Lindgren model AMS-8923 with phi-axis mechanical positioner and distributed axis electronically-switched theta ring. This means that the phi (azimuth) axis of a mobile device under test, whose long vertical axis is oriented vertically inside the chamber and whose face points at horizon, will rotate mechanically about the long z-axis during testing. The elevation axis data is obtained by fast switching between 23 wideband dual-polarized probe antennas (Vivaldi style, ETS Lindgren model number 3165-01). Probes are spaced at 15° around a large ring that is approximately 3meters in diameter (1.5 meters in radius, between the device-under-test and the front plane of each probe), from theta=-165° (15° from nadir) up through zenith to +165° (15° from nadir, 180° opposite in phi/azimuth). See **Figure 2**.

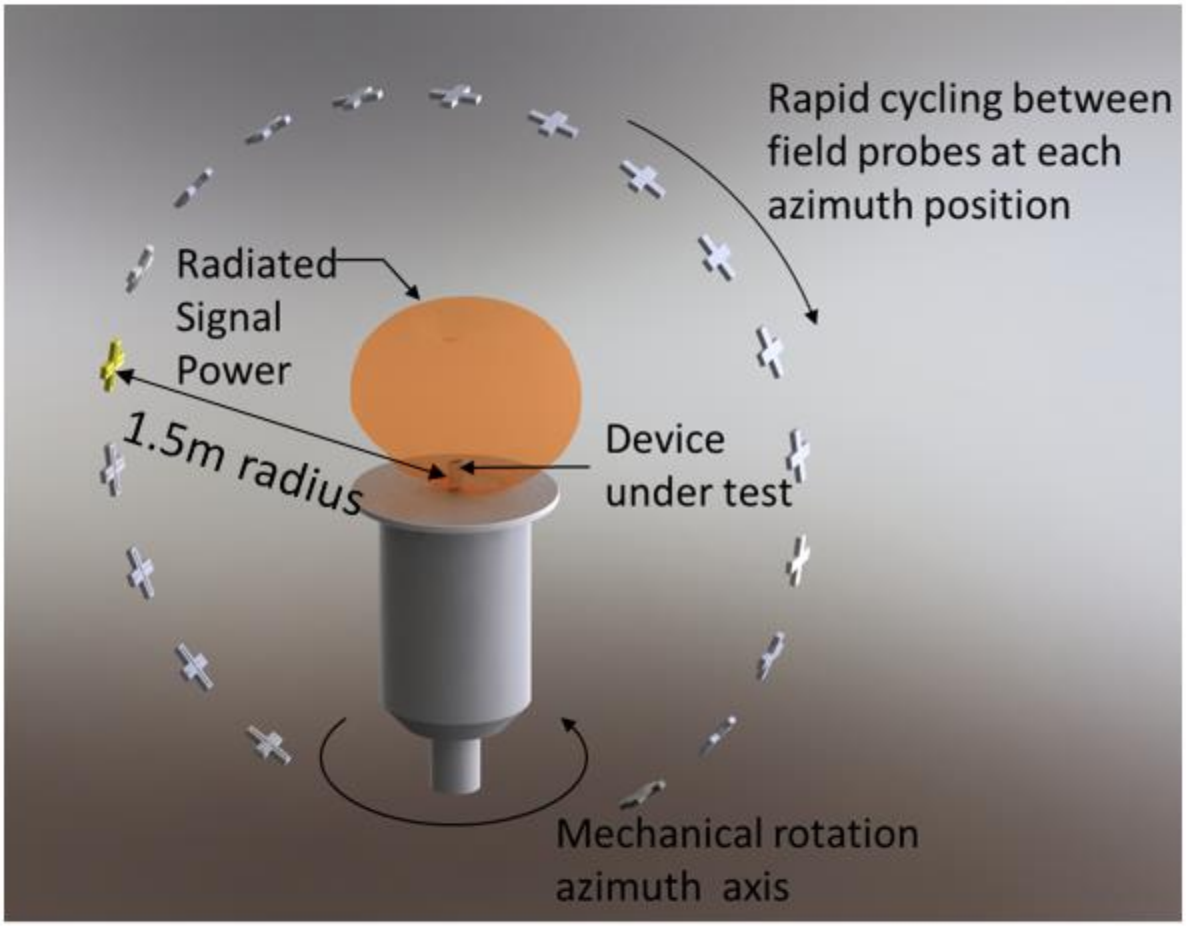


Figure 2: Orientation of Device under test (DUT) inside chamber during testing

The output of each probe is fed through a switching matrix, exiting the chamber at an RF-sealed port, through a low-noise amplifier and is received at a spectrum analyzer (Agilent N9010 EXA Signal Analyzer, S/N MY52221249

5.2. 2D dual-axis peak leakage measurement method

The purpose of the 2D-dual-axis peak-leakage measurement is to rotate the shielded transmitter through multiple orthogonal axes and two orthogonal polarizations to identify the angle/polarization combination which yields highest power. The measurement is performed at 750 / 850 / 1500 / 1800 / 2000 / 2600 / 5400 MHz. This peak leakage power is compared to the peak power that is radiated by the unshielded transmitter, but attached to the Privoro, LLC case. The peak power of the unshielded case is identified through a full 3D EIRP measurement of the unshielded case over all space at dual orthogonal polarizations.

For the shielded measurement, the measurement axes are the front-back elevation axis of the device and the azimuth axis of the device. Shielded measurements were initially performed at 2600 MHz with a measurement setup similar to the unshielded measurement. This measurement configuration offered 109 dB dynamic range, which is insufficient to characterize the manufacturer's expected attenuation level. In order to increase dynamic range, the probe antenna was manually positioned closer to the DUT, from the standard 1.5m range radius to 17.85" from the phase center of the probe antenna to the center of rotation of the DUT. While this increased the dynamic range by the amount of recaptured path spreading loss, it was no longer possible to sample the power over all 3D space. It is necessary to reposition the DUT and probe antenna manually to obtain different cut axes and different probe polarizations, respectively.

Figure 3 shows DUT orientation for elevation and azimuth pattern cuts using the revised 2D "close-in" method. The DUT is positioned so that when lying on its side and rotated with the positioner table, a front-back elevation cut is affected. When the DUT is oriented vertically on the table (how it would be oriented in a typical OTA test), rotation affects an azimuth cut.

The probe antenna is shown in two orthogonal polarization orientations. Probe polarization refers to the equivalent polarization, had the DUT been positioned per normal protocol. When the probe is horizontal in the front-back elevation cut, this is equivalent to the theta (vertical) polarization, and when oriented vertically is equivalent to the phi (horizontal) polarization. The reverse is true for the azimuth axis cut. A vertical probe is equivalent to the standard theta (vertical) polarization, and horizontal probe is equivalent to the standard phi (horizontal) polarization.

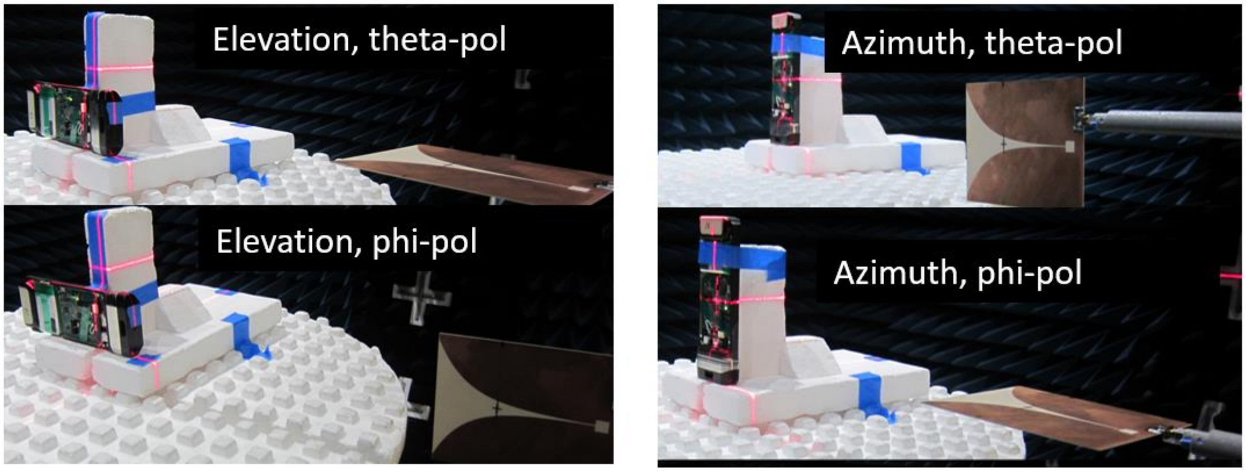


Figure 3: DUT orientation for elevation and azimuth pattern cuts. Probe antenna is shown in two orthogonal polarization orientations. Probe polarization refers to the equivalent polarization, had the DUT been positioned per normal protocol.

At the 750, 820 and 1500 MHz measurements, the patterns are broad enough that any uncertainty about the true angular location of the peak-of-beam is negligible with respect to the measured attenuation values. For 1800, 2000, 2600 and 5400 MHz, the shape of the elevation and azimuth patterns introduced enough uncertainty about the location of the true peak-of-beam that the orthogonal side-to-side elevation axis of the shielded transmitter was measured as well.

While the 3D EIRP measurement of the unshielded transmitter is calibrated and referenced to an equivalent isotropic radiator, the measurement of the close-in transmitter is not calibrated to an equivalent isotropic source. In order to compare the two measurements directly for calculating attenuation, it is necessary to scale the EIRP of the shielded transmitter by some correction factor "CF" so that it is directly comparable to an equivalent isotropic source. The technique used here is identical to that used in the standard antenna gain substitution method, where an antenna of known gain is measured, and the difference between the actual measured signal level and the expected antenna gain is the path loss or correction factor, which is applied to all subsequent measurements.

In equation form, this becomes

$EIRP_{2D\ shielded\ cal} = EIRP_{2D,shielded,uncal} + CF$ (CF = Correction Factor)

$CF = EIRP_{3D,unshielded,cal} - EIRP_{2D,unshielded,uncal}$

Finally, $EIRP_{2D\ shielded,cal}$ is subtracted from the peak calibrated unshielded transmitter EIRP to arrive at the minimum attenuation value at each frequency.

$$Minimum\ Attenutation = Peak\ unshielded\ EIRP - Peak\ shielded\ EIRP$$
$$= EIRP_{3D,unshielded,cal} - EIRP_{2D\ shielded,cal}$$

Theoretically, the close-in uncalibrated 2D pattern of the unshielded transmitter will exactly match the calibrated 3D pattern in shape, scaled by the difference in path loss. In reality, there is a slight alignment error between the probe antennas used in the two measurements. This leads to uncertainty in the actual correction factor. Some judgement must be used in selecting the azimuth angle in the 2D close-in azimuth pattern and the 3D calibrated azimuth pattern, from which to calculate the correction factor. Appendix A discusses this in more detail.

The complete process is summarized as follows:

1) Measure the EIRP (effective isotropic radiated power) of the transmitter installed in the case but without privacy guard (i.e., unshielded transmitter) at the matrix of azimuth (phi) and elevation (theta) angles that include phi=[0°:15°:180°] and theta=[-165°:15°:165°]. The resulting set of dual-polarized EIRP measurements is automatically calibrated against an equivalent isotropic radiator by subtracting out all path and cable losses using standard antenna gain substitution techniques.
    - The resulting dataset can also be used to calculate the Total Radiated Power (TRP) of the unshielded transmitter, which is not used in this measurement.
    - The peak EIRP angle and polarization from this measurement is used as the unshielded transmitter baseline measurement.

Since a potential attacker has no knowledge of the orientation of the antenna, the peak EIRP of the unshielded transmitter identified in the 3D measurement is chosen regardless of polarization.

2) Measure the unshielded transmitter again using the close-in 2D dual-axis measurement technique. The close-in unshielded transmitter measurements can be calibrated against the calibrated EIRP unshielded measurement to obtain a correction factor which is applied to the shielded transmitter measurement.
3) Measure the shielded transmitter using the close-in 2D dual-axis measurement technique. Identify the peak leakage angle and polarization; correct the measurement using the correction factor above.

6. Results

This section documents the following results:

- Calibrated peak 3D EIRP for the unshielded case
- Uncalibrated 2D close-in dual-polarized EIRP taken at the correction-factor angle for the unshielded transmitter
- Uncalibrated 2D close-in dual-polarized EIRP taken at the correction-factor angle for the shielded transmitter
- Uncalibrated 2D close-in peak leakage value
- Minimum attenuation of the case calculated per above

Freq [MHz]	Peak unshielded EIRP $(EIRP_{3D,unshielded,cal})$	Peak shielded uncalibrated EIRP $(EIRP_{2D,shielded,uncal})$	Azimuth angle from 3D measurement for correction factor	Unshielded, uncalibrated EIRP at correction factor angle $(EIRP_{3D,unshielded,uncal})$	Unshielded, calibrated EIRP at correction factor angle $(EIRP_{3D,unshielde$	Correction factor (CF)	Calibrated shielded leakage $(EIRP_{2D\ shielded,cal})$	Minimum attenuation
750	17.35	-125.91	0° (face of phone)	13.83	15.74	1.91	-124.00	141.35
850	8.84	-122.73	180° (back of phone)	8.47	8.48	0.01	-122.72	131.56
1500	20.08	-124.81	90° (right side of phone)	12.90	14.24	1.34	-123.47	143.55
1800	22.67	-119.57	90° (right side of phone)	14.91	18.52	3.61	-115.96	138.63
2000	12.19	-115.16	90° (right side of phone)	13.79	7.26	-6.53	-121.69	133.88
2600	13.03	-98.56	-90° (left side of phone)	16.30	10.90	-5.40	-103.96	116.99
5400	19.64	-96.68	0° (face of phone)	18.26	19.64	1.38	-95.30	114.94

$EIRP_{2D\ shielded\ cal} = EIRP_{2D,shielded,uncal} + CF$ (CF = Correction Factor)

$CF = EIRP_{3D,unshielded,cal} - EIRP_{2D,unshielded,uncal}$

$Minimum\ Attenutation = Peak\ unshielded\ EIRP - Peak\ shielded\ EIRP = EIRP_{3D,unshielded,cal} - EIRP_{2D\ shielded,cal}$

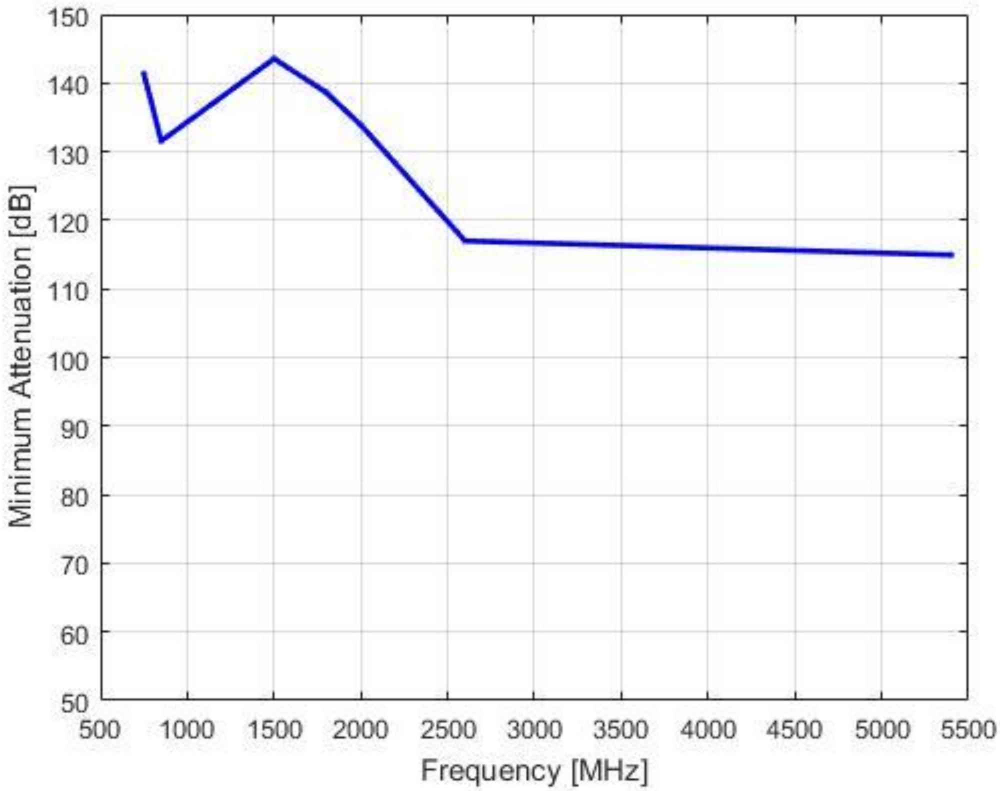


Figure 4: Minimum Attenuation vs Frequency

Appendix A: Pattern comparisons taken from the 3D calibrated measurements and the close-in dual-axis measurements

This Appendix discusses the choice of spatial orientations from which to derive the correction factor.

In the standard antenna gain substitution technique, the path losses (including system cabling, equipment and free space losses) of an antenna range are calibrated out by measuring an antenna with a known gain value and referencing all device-under-test (DUT) measurements to the specific power level that was recorded for the known antenna. It is assumed that all measurements are made in the far-field, and that chamber multi-path is either negligible or is taken as an uncertainty term.

The 3D EIRP readings of the unshielded transmitter were taken in a configuration that allows for referencing back to an isotropic source. This reference calibration measurement is part of BluFlux's standard measurement process for performing certified calibrated over-the-air measurements. A calibrated dipole of known gain traceable to NIST standards is used to calibrate out the path spreading loss between the center of rotation of the measurement table, measurement antenna of unknown frequency-dependent gain, cabling and finally switch matrix losses before being measured at a calibrated spectrum analyzer. Therefore, the 3D EIRP measurements of the unshielded transmitter bear NIST traceability.

It was determined that the shielded transmitter did not produce power levels high enough to be measured using the same configuration as the unshielded transmitter. In order to improve the dynamic range of the measurement, it was necessary to take the power readings at a closer range distance than the standard 1.5-meter measurement radius of the distributed-axis measurement system. In doing so, these "close-in 2D" power readings lost the benefit of direct calibration against a dipole of known gain, since the cabling, path losses and probe antenna are all different. The team considered two options for reacquiring a calibrated reference:

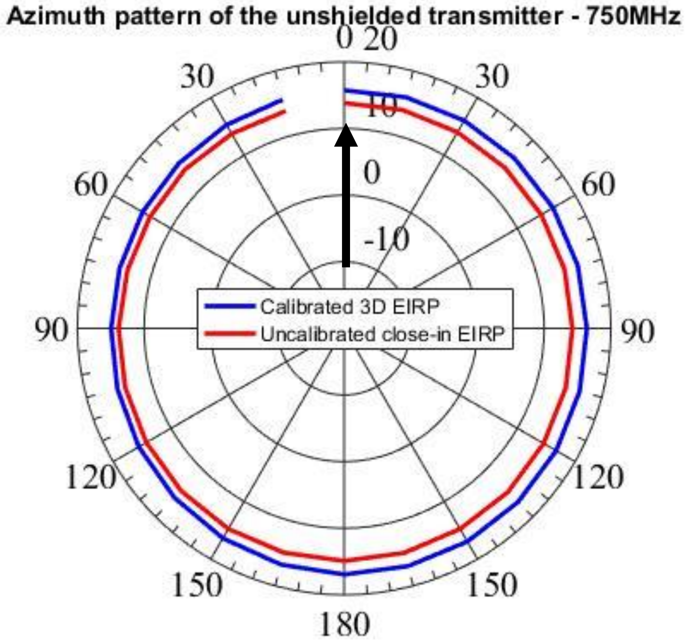
- Re-calibrate the chamber against the set of calibrated dipoles for every measurement frequency
- Re-measure the power output of the unshielded transmitter with the new close-in configuration, and compare the power readings from this new uncalibrated measurement to those of the calibrated measurement. The difference between them is the theoretical calibration factor.

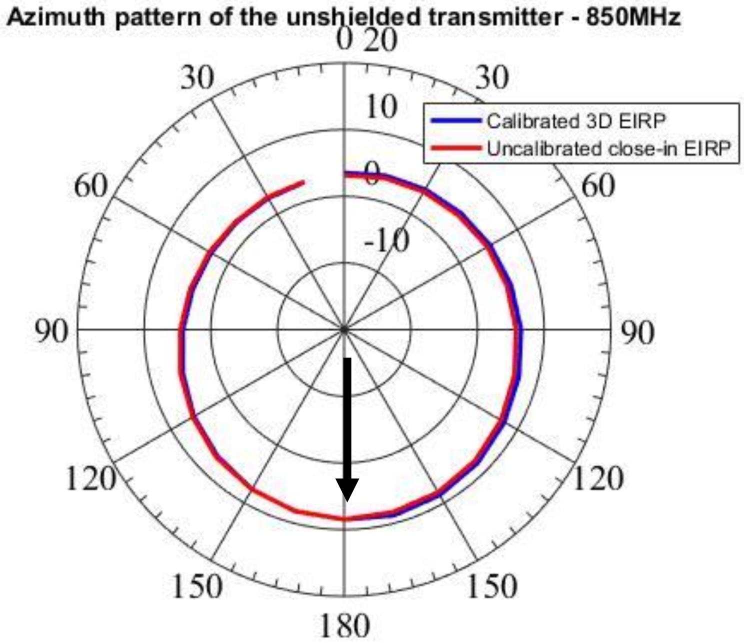
Theoretically, the uncalibrated measurement of the unshielded transmitter at all points in space will be identical to the calibrated unshielded measurement at all points in space, with some constant bias offset. The constant bias offset at any frequency is equal to the frequency-dependent path loss, measurement / probe antenna characteristics, cable losses and switch matrix losses. This constant bias offset, known as the correction factor ("CF"), is then applied to all future uncalibrated shielded measurements so that the 3D unshielded measurements are now directly relatable to the shielded measurements.

In reality, the correction factor is constant over only a portion of the 2D space over which the two close-in measurements were made. This is because of the greater sensitivity of the alignment height of the probe antennas in the close-in measurement versus the farther-out 3D measurements. While the azimuth plane patterns of the unshielded measurement were used to select the correction factor, the elevation plane pattern of the unshielded device can play a large role in perturbing the stability of the azimuth plane pattern, if the EIRP is measured at an azimuth angle where the elevation pattern varies wildly.

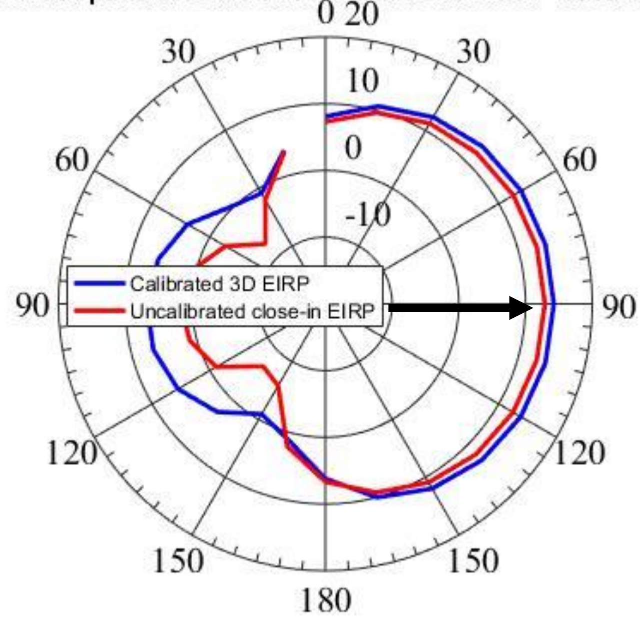
Therefore, the azimuth pattern of the 2D close-in measurement of the unshielded transmitter was examined and compared to the azimuth-plane pattern of the calibrated 3D measurement at every frequency. The angle from which to select the correction was chosen based on the stability of the pattern over a particular angular sector. The azimuth pattern comparison for each frequency is shown in the figures below. Black arrows point to the angle from which the correction factor was taken. It can be seen that the correction factor is taken from a very stable point on the azimuth pattern, generally coinciding with the peak EIRP of both patterns. The difference between the two patterns is preserved with roughly 1 dB over a broad sector about the angle that is chosen.

The 2000 and 2600 MHz patterns exhibit variation in their elevation patterns which explains the discrepancy between the two azimuth patterns at those frequencies.

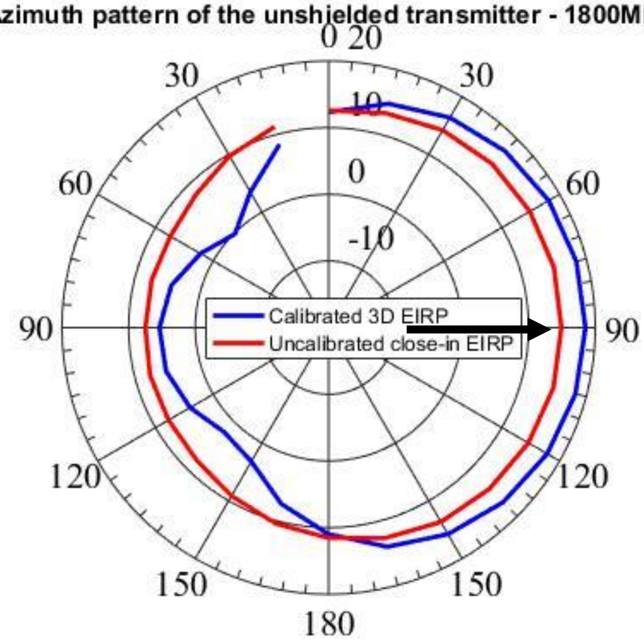

Azimuth pattern of the unshielded transmitter - 750MHz
0 20
30
30
10
60
0
60
-10
90
90
Calibrated 3D EIRP
Uncalibrated close-in EIRP
120
120
150
150
180


Azimuth pattern of the unshielded transmitter - 850MHz
0 20
30
30
10
Calibrated 3D EIRP
Uncalibrated close-in EIRP
60
0
60
-10
90
90
120
120
150
150
180

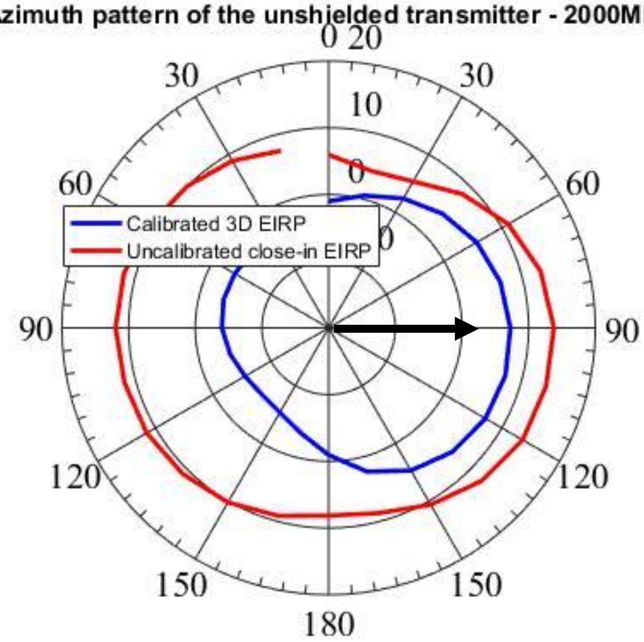
Azimuth pattern of the unshielded transmitter - 1500MHz



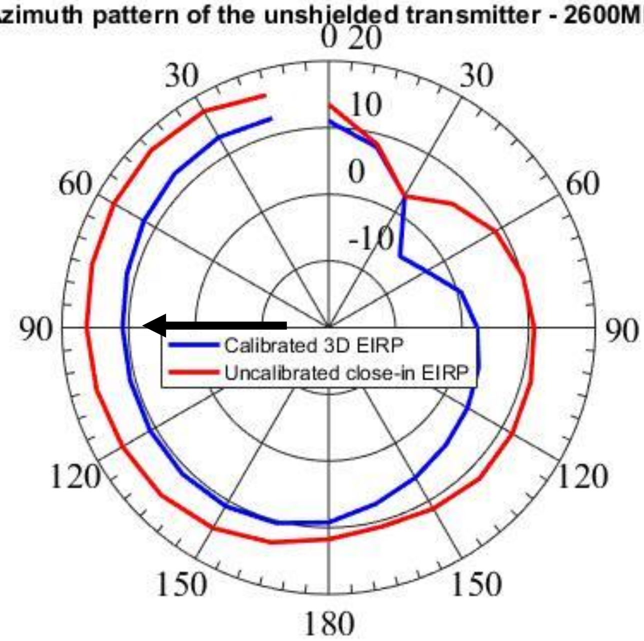
Azimuth pattern of the unshielded transmitter - 1800MHz



Azimuth pattern of the unshielded transmitter - 2000MHz



Azimuth pattern of the unshielded transmitter - 2600MHz



Azimuth pattern of the unshielded transmitter - 5400MHz