Description and Technical Parameters – ST5000-2.4

The ST5000-2.4 terminal is comprised of a 2.4m circular reflector antenna, an antenna positioner, and an antenna control module. The antenna positioner and control module are the same as those used in Harris CapRock's SpaceTrack 4000 series of stabilized antennas. The SpaceTrack 4000 has been previously licensed by the FCC in C-band and Ku-band ESV configurations and has years of proven experience in the field. Thus, the FCC can be assured that ST5000-2.4 will operate as designed to avoid potential interference to adjacent satellites.

SUMMARY OF TECHNICAL PARAMETERS – ST5000-2.4

Characteristic	**C-band**	**Ku-band**	**Ka-band**
Antenna diameter	2.4m	2.4m	2.4m
Type of Antenna	Circular reflector	Circular reflector	Circular reflector
Peak Power (SSPA)	200 watts	125 watts	40 watts
Transmit Bandwidth	1 MHz to 72 MHz	1 MHz to 72 MHz	1 MHz to 216 MHz
Transmit Gain	38 dBi	43 dBi	54.7 dBi
EIRP	58.3 dBW	62.2 dBW	68.9 dBW
Data Rate	20 Mbps Tx / 100 Mbps Rx	20 Mbps Tx / 100 Mbps Rx	40 Mbps Tx/ 300 Mbps Rx
Emission Designators	1M00G7D to 20M0G7D	1M00G7D to 20M0G7D	1M00G7D to 40M0G7D
Transmit Polarization	LHCP/RHCP Horizontal/Vertical	Horizontal/Vertical	LHCP/RHCP
Transmit Max PSD	21.3 dBW/4kHz	25.2 dBW/4kHZ	29.0 dBW/4kHz
Transmit Beamwidth	0.57 degrees	0.3 degrees	.14 degrees
Receive G/T	16.4 dB/K	24.5 dB/K	26.5 dB/K
Receive Bandwidth	Up to 72 MHz	Up to 72 MHz	Up to 216 MHz
Receive Polarization	LHCP/RHCP Horizontal/Vertical	Horizontal/Vertical	LHCP and RHCP
Feed Flange Power	106.2 Watts	74.5 Watts	26.4 Watts
ERP	409 kW	1.02 MW	4.7 MW
Signal Modulation	Up to 32 APSK	Up to 32 APSK	Up to 32APSK

The ST5000-2.4 positioner system is designed to provide stable pointing to GSO satellites during range of motion associated with maritime operations, as well as track predictable NGSO satellite orbit paths under the same maritime operational conditions. Harris CapRock's current test program confirms the terminals ability to successfully track and communicate with O3b satellites, and there have been no reported cases of interference in connection with ST-5000-2.4 operations.

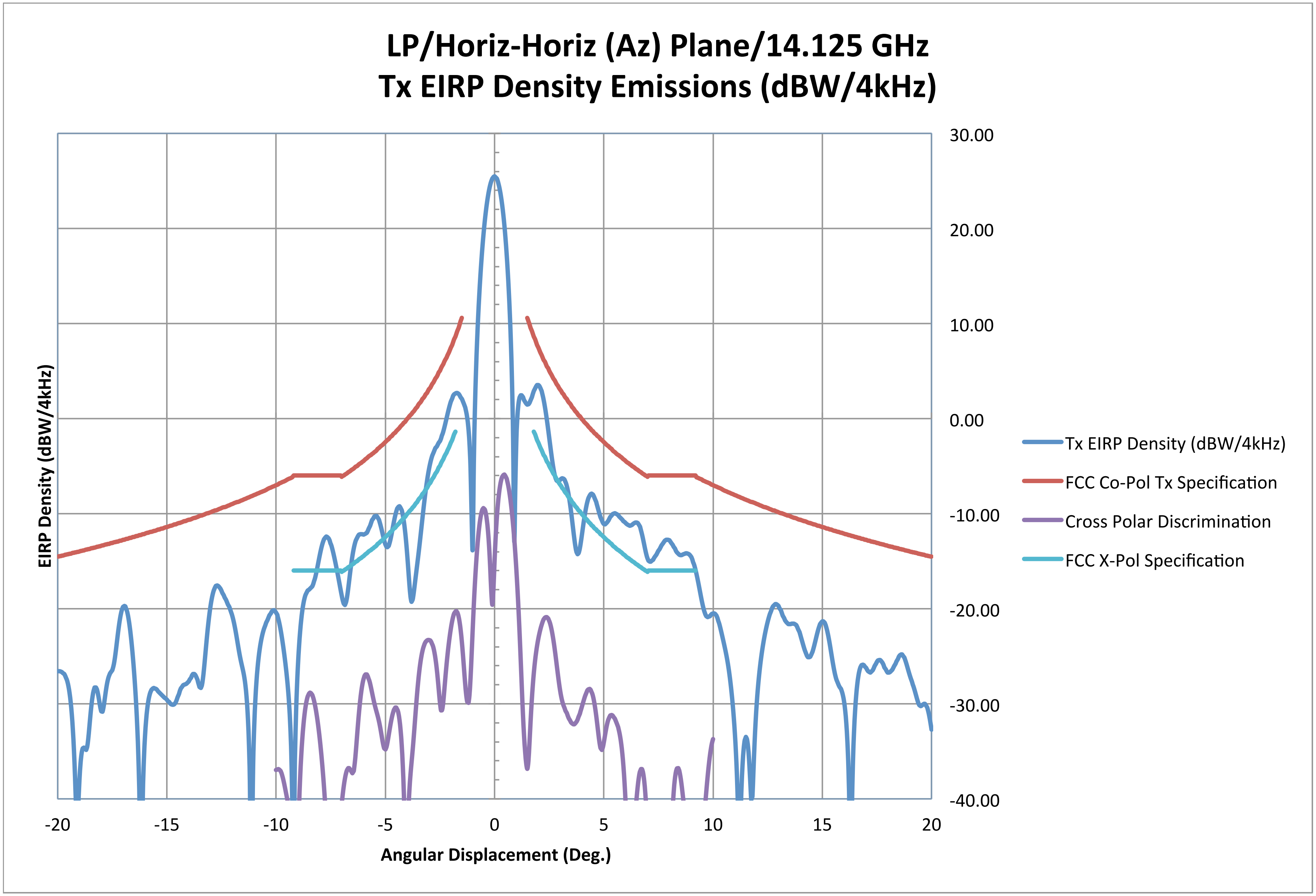
Harris CapRock's ST5000-2.4 terminal is designed to meet the FCC's ESV operational requirements for communication with GSO satellites, which have been extended by analogy to full-motion antennas communicating with the O3b system. These parameters include: (i) maintaining off-axis EIRP to the levels set forth in the applicable FCC mask (in the case of Ka-band, Section 25.138); (ii) pointing accuracy of 0.2° or better; (iii) automatic cessation of emissions within 100 ms if pointing offset exceeds 0.5°; and (iv) transmissions will not resume until pointing accuracy is within 0.2°. The technical characteristics of the terminal's positioner system are set forth in the follow tables.

ANTENNA MOTION PARAMETERS - ST5000-2.4

Azimuth	Continuous coverage over 360º
Elevation	0 to 90º antenna elevation
Position accuracy	0.2º (auto-disable at 0.5 º offset)
Tracking capability	8º/sec

Additional information regarding the ST5000-2.4 terminal, including antenna performance plots, link budgets, and a radiofrequency hazard assessment are included as attachments hereto.

Annex 1 – Antenna Performance Plots



LP/Horiz-Horiz (Az) Plane/14.125 GHz
Tx EIRP Density Emissions (dBW/4kHz)
EIRP Density (dBW/4kHz)
30.00
20.00
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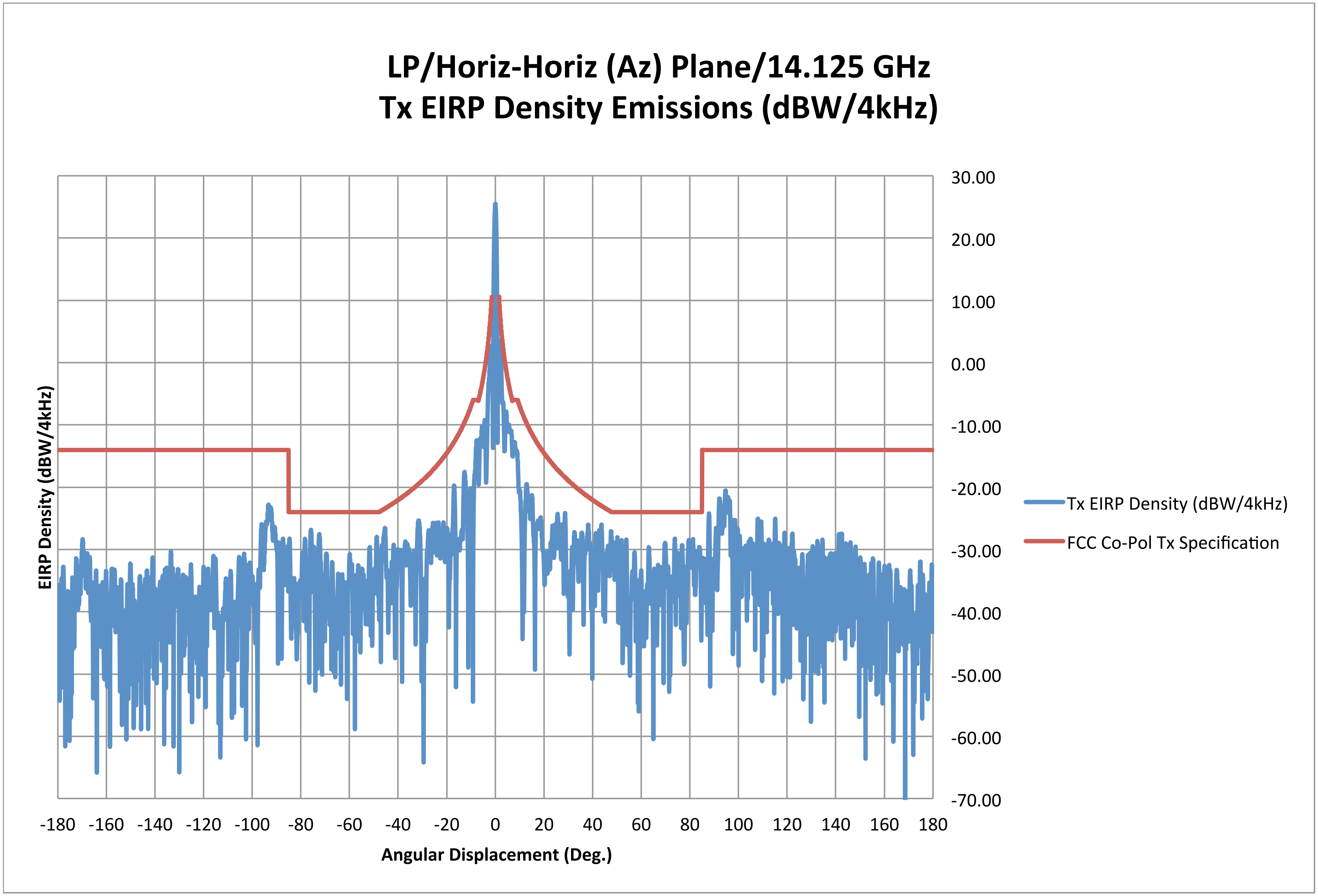
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification
Cross Polar Discrimination
FCC X-Pol Specification


LP/Horiz-Horiz (Az) Plane/14.125 GHz
Tx EIRP Density Emissions (dBW/4kHz)
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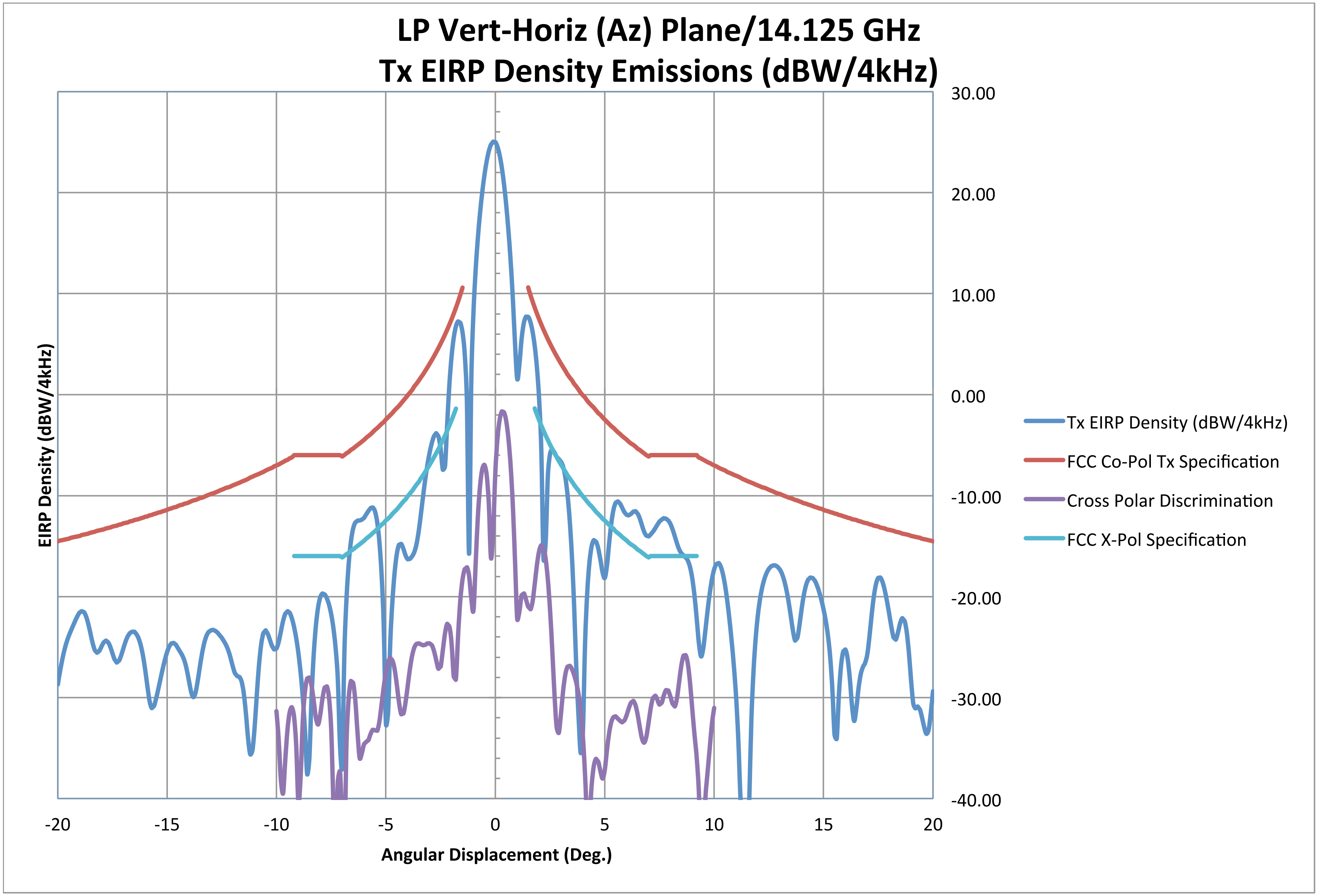
EIRP Density (dBW/4kHz)
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification



LP Vert-Horiz (Az) Plane/14.125 GHz
Tx EIRP Density Emissions (dBW/4kHz)
EIRP Density (dBW/4kHz)
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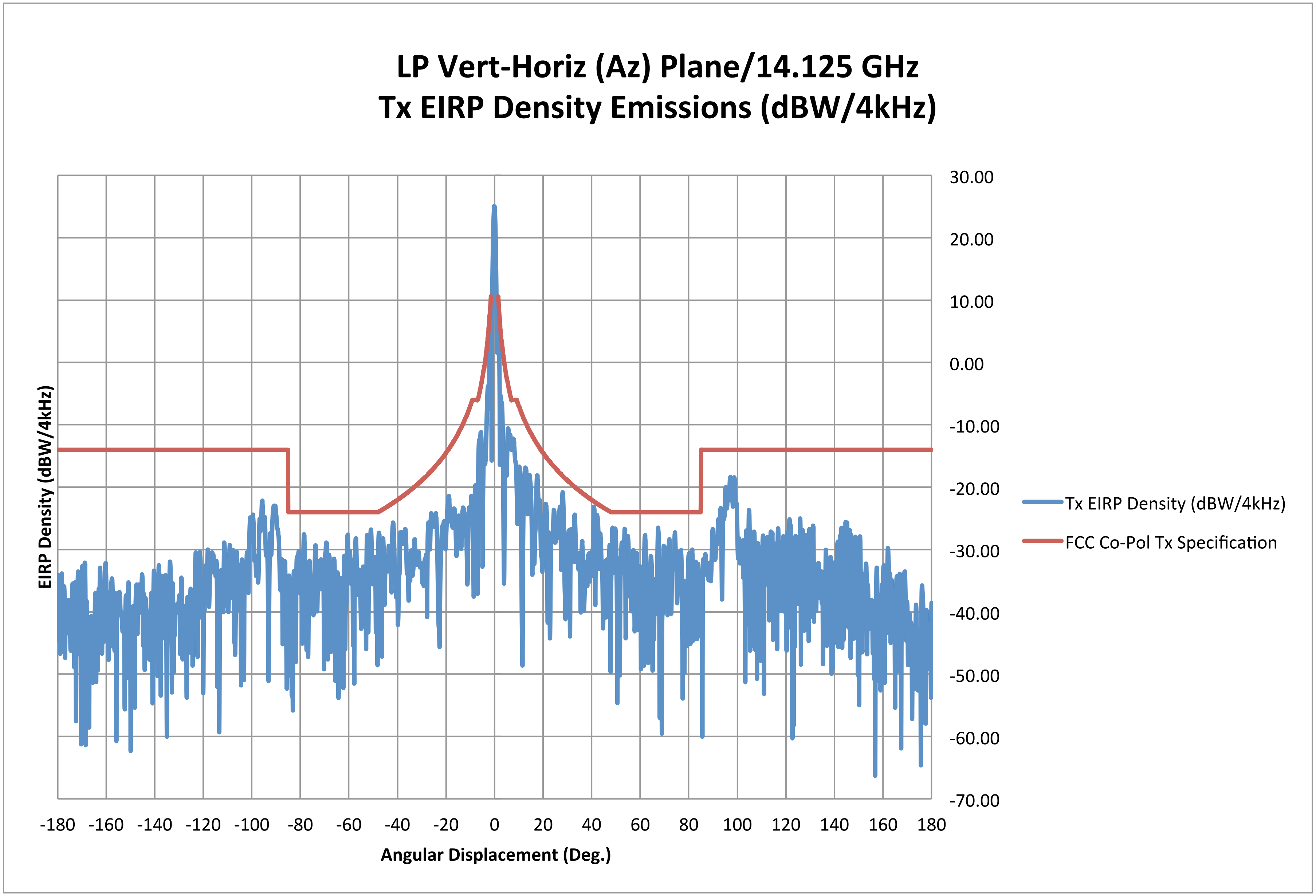
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification
Cross Polar Discrimination
FCC X-Pol Specification



LP Vert-Horiz (Az) Plane/14.125 GHz
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EIRP Density (dBW/4kHz)
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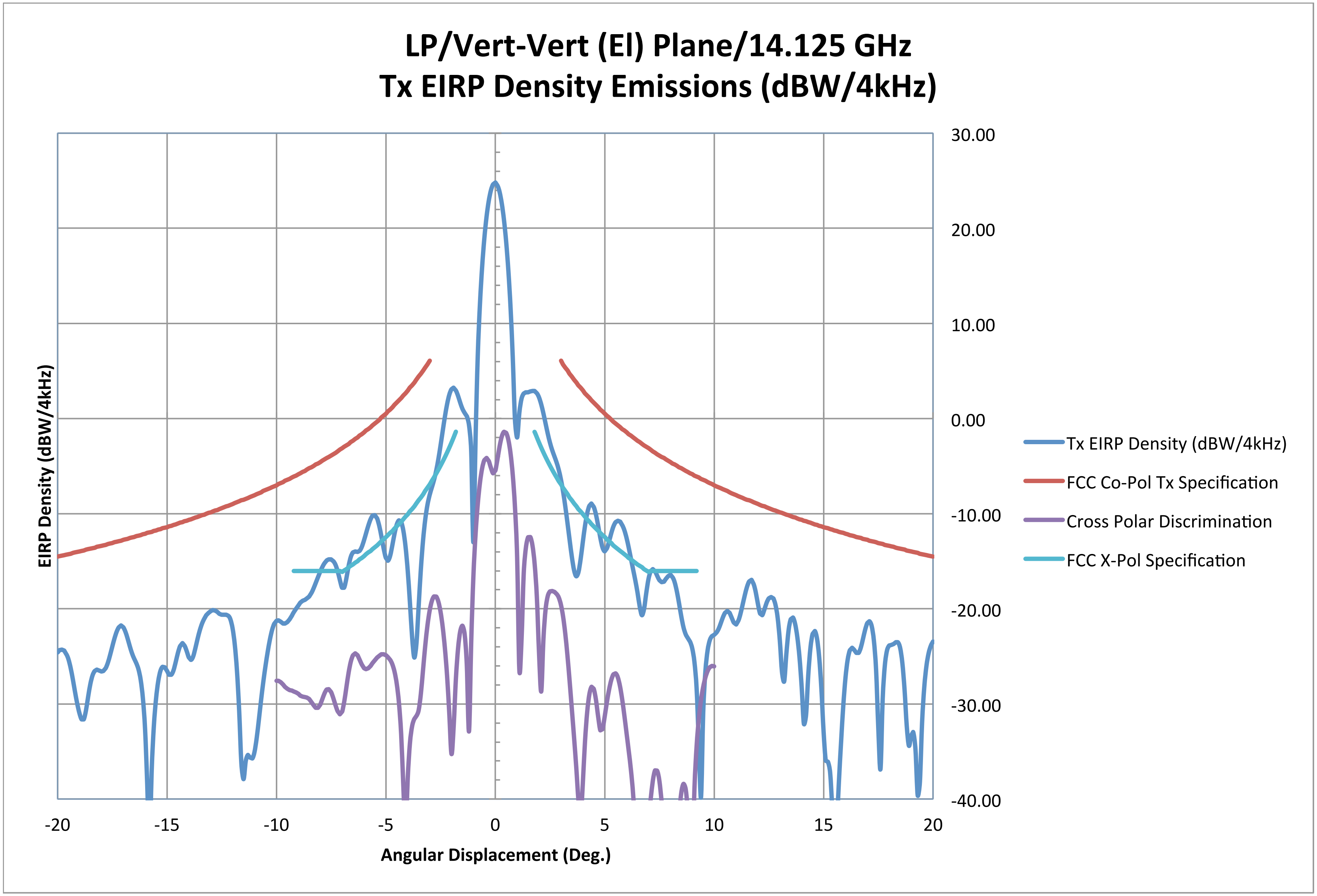
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification


LP/Vert-Vert (El) Plane/14.125 GHz
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EIRP Density (dBW/4kHz)
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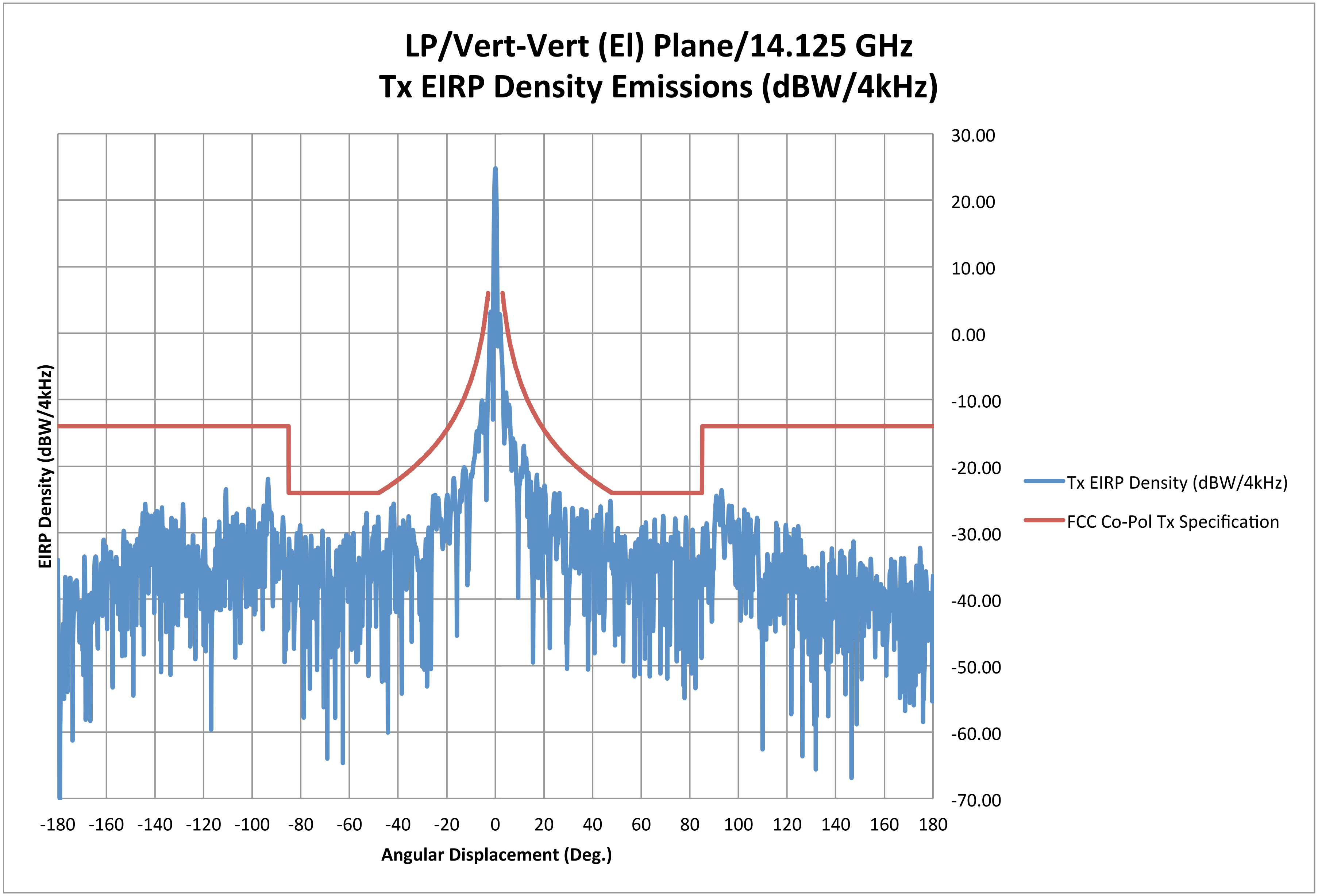
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification
Cross Polar Discrimination
FCC X-Pol Specification



LP/Vert-Vert (El) Plane/14.125 GHz
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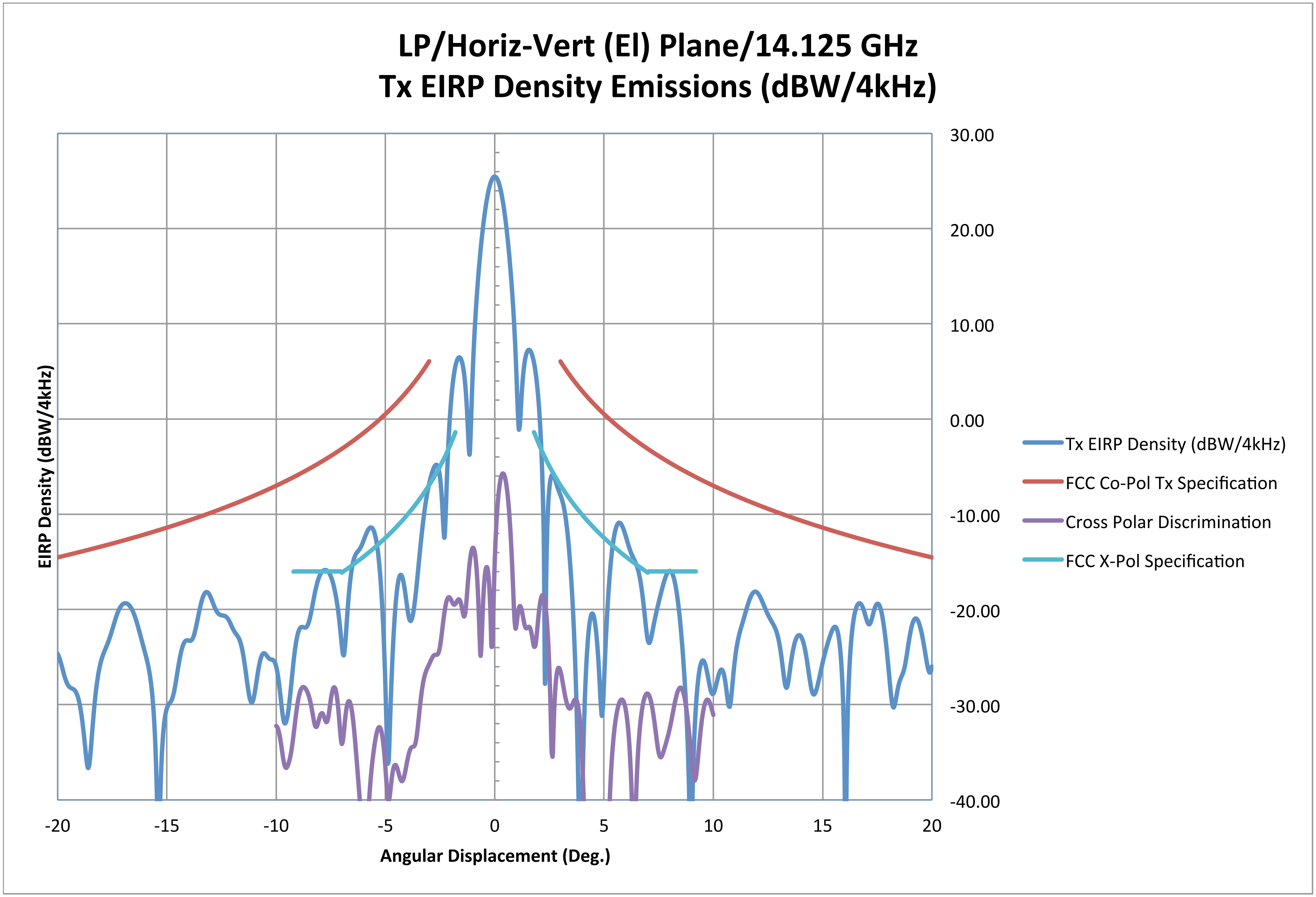
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification


LP/Horiz-Vert (El) Plane/14.125 GHz
Tx EIRP Density Emissions (dBW/4kHz)
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EIRP Density (dBW/4kHz)
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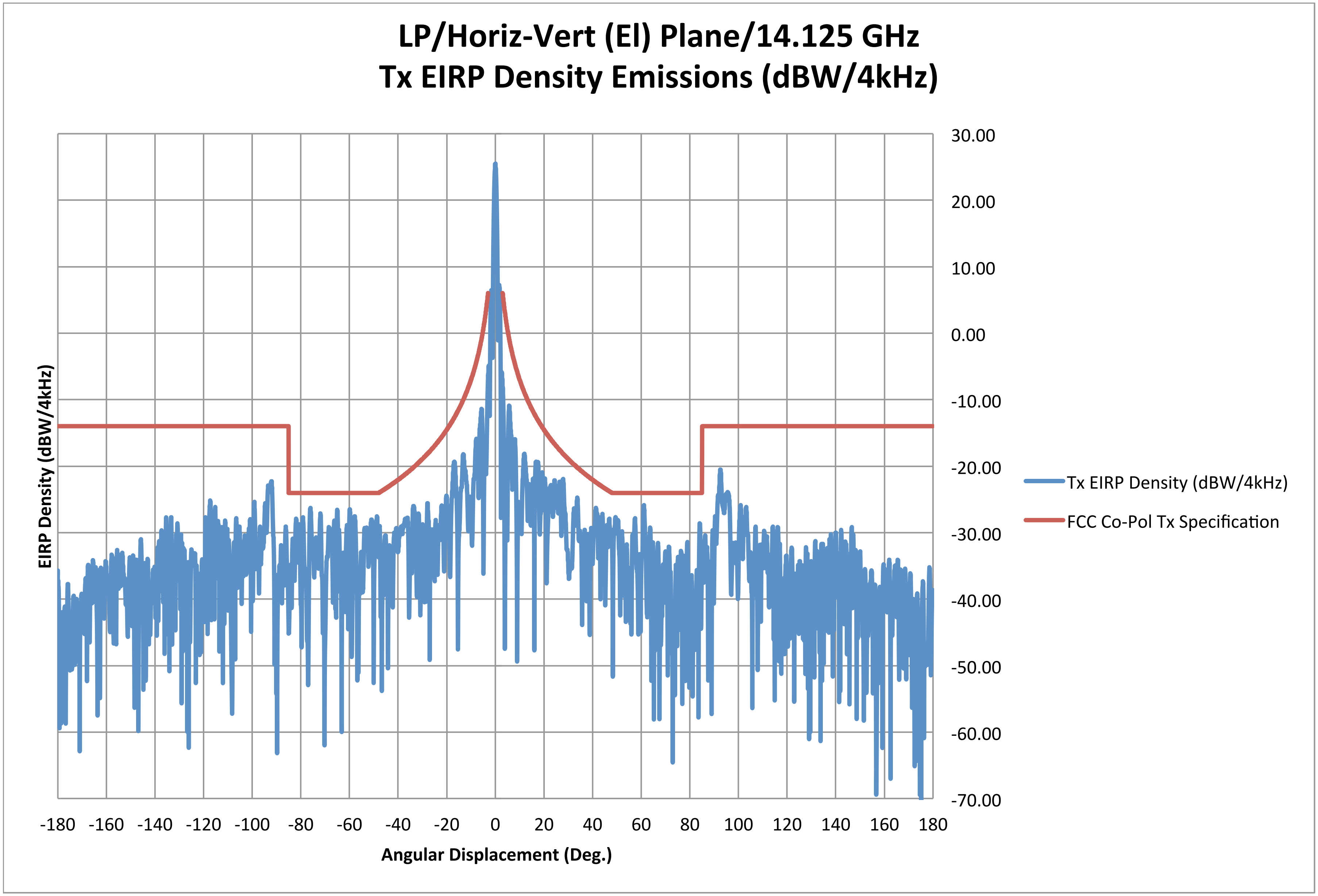
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification
Cross Polar Discrimination
FCC X-Pol Specification


LP/Horiz-Vert (El) Plane/14.125 GHz
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EIRP Density (dBW/4kHz)
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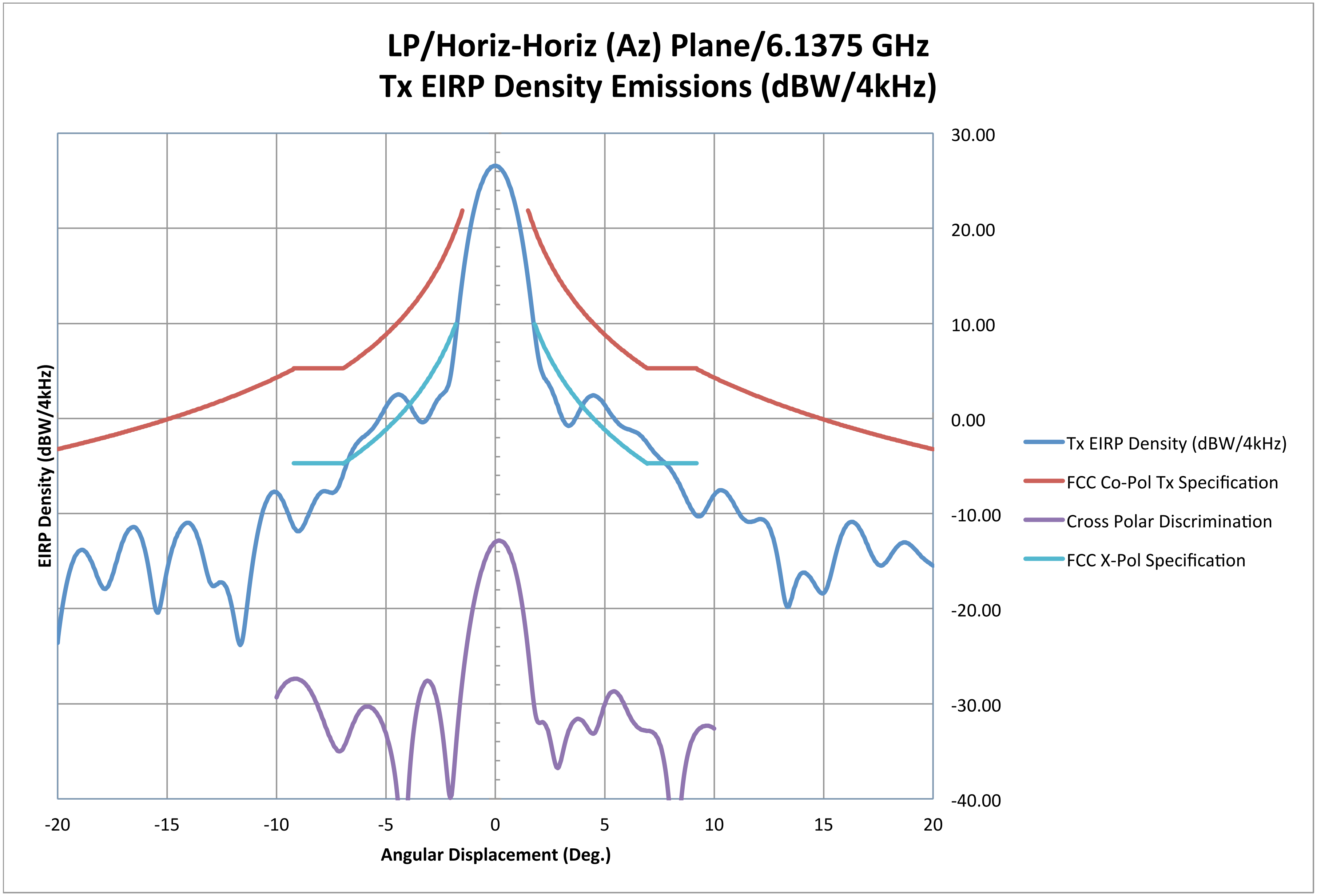
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification


LP/Horiz-Horiz (Az) Plane/6.1375 GHz
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EIRP Density (dBW/4kHz)
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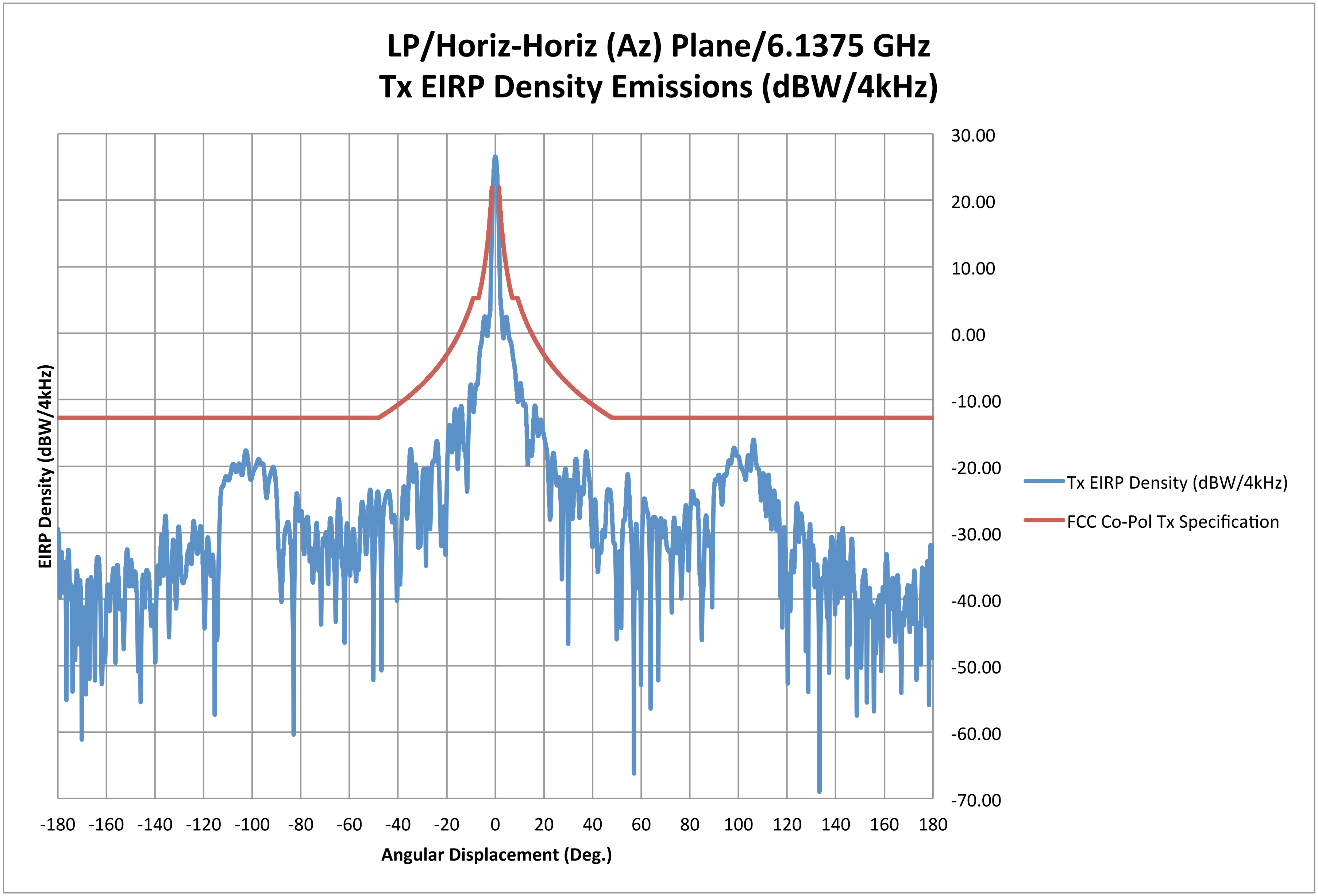
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification
Cross Polar Discrimination
FCC X-Pol Specification



LP/Horiz-Horiz (Az) Plane/6.1375 GHz
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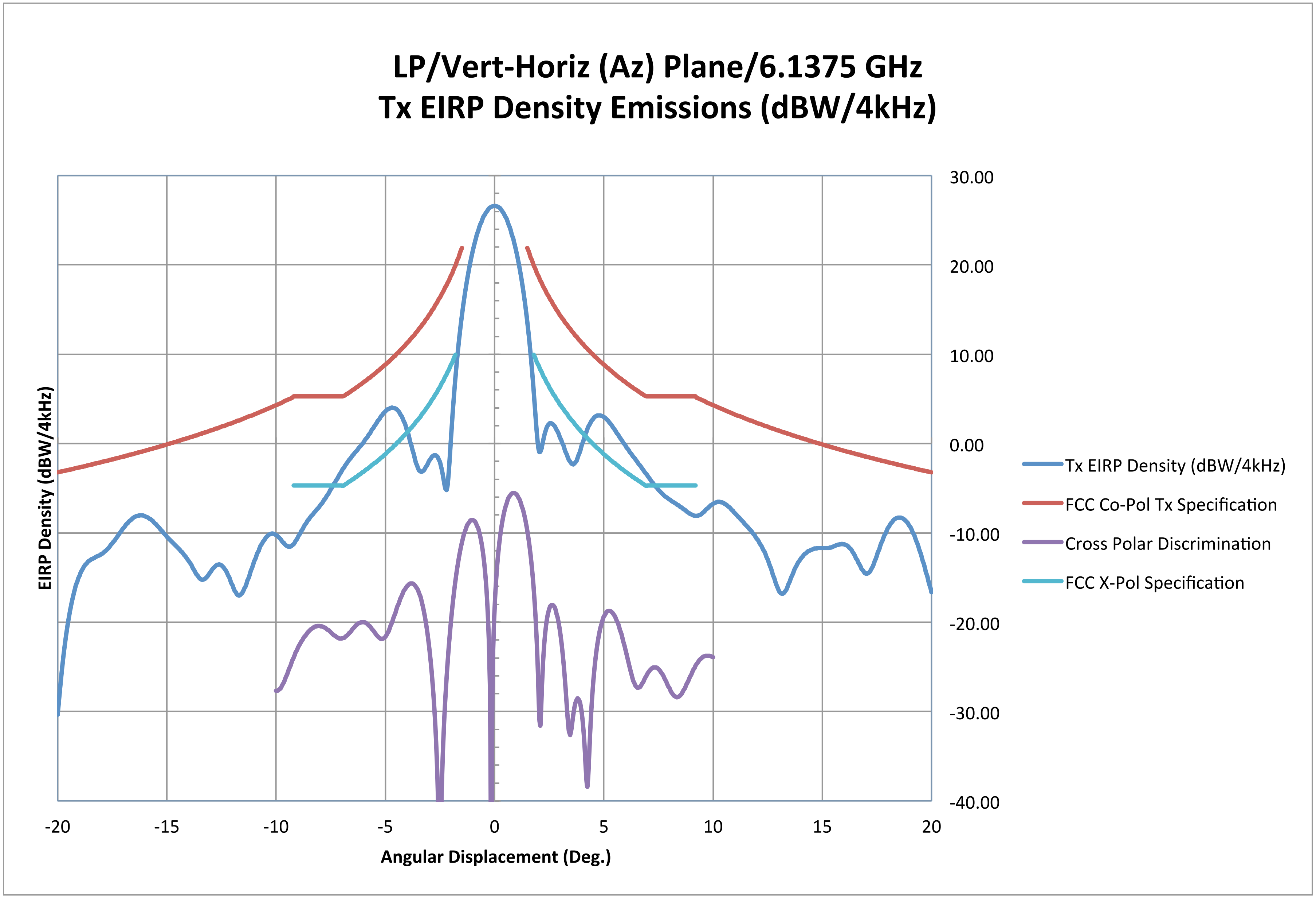
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification


LP/Vert-Horiz (Az) Plane/6.1375 GHz
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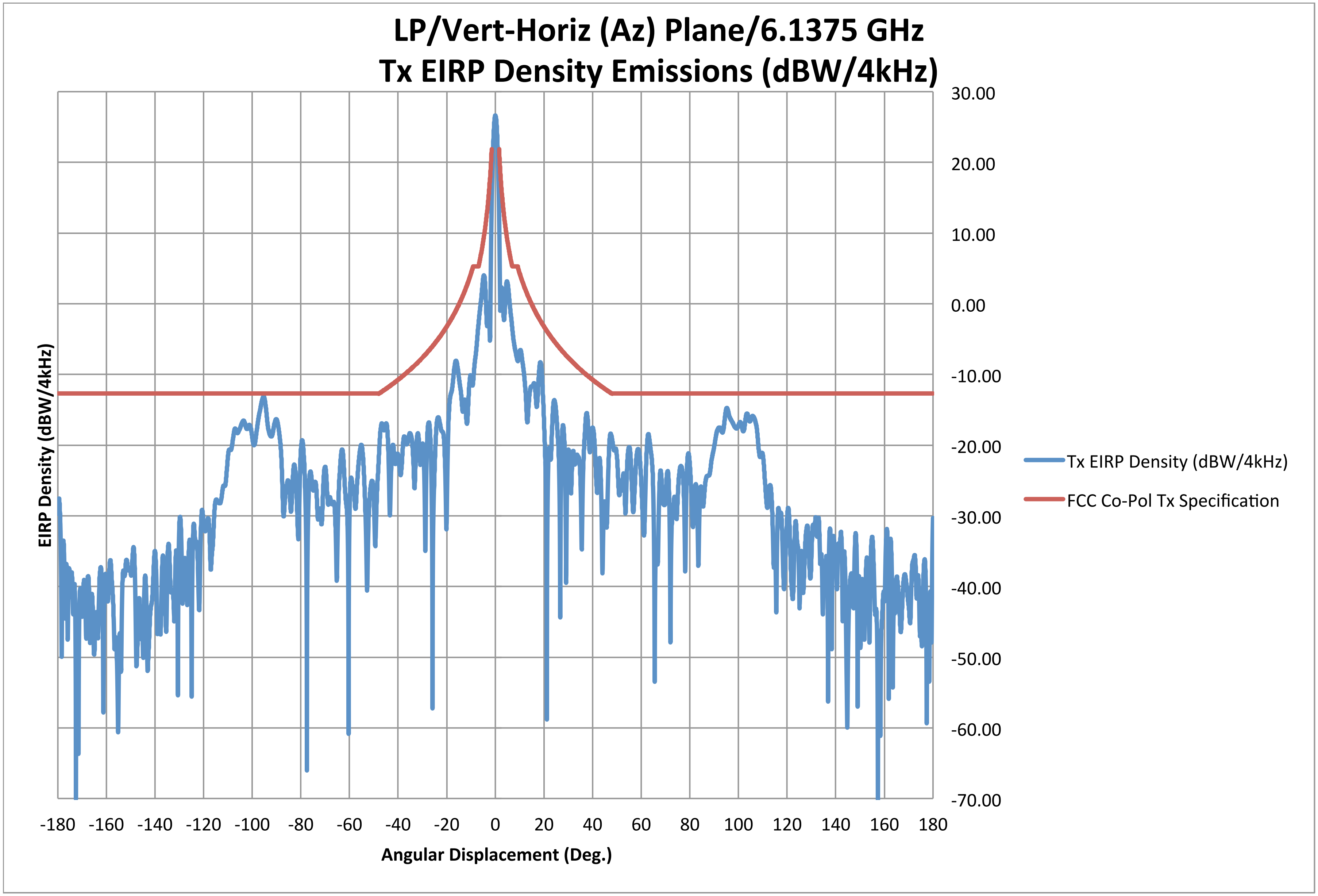
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification
Cross Polar Discrimination
FCC X-Pol Specification


LP/Vert-Horiz (Az) Plane/6.1375 GHz
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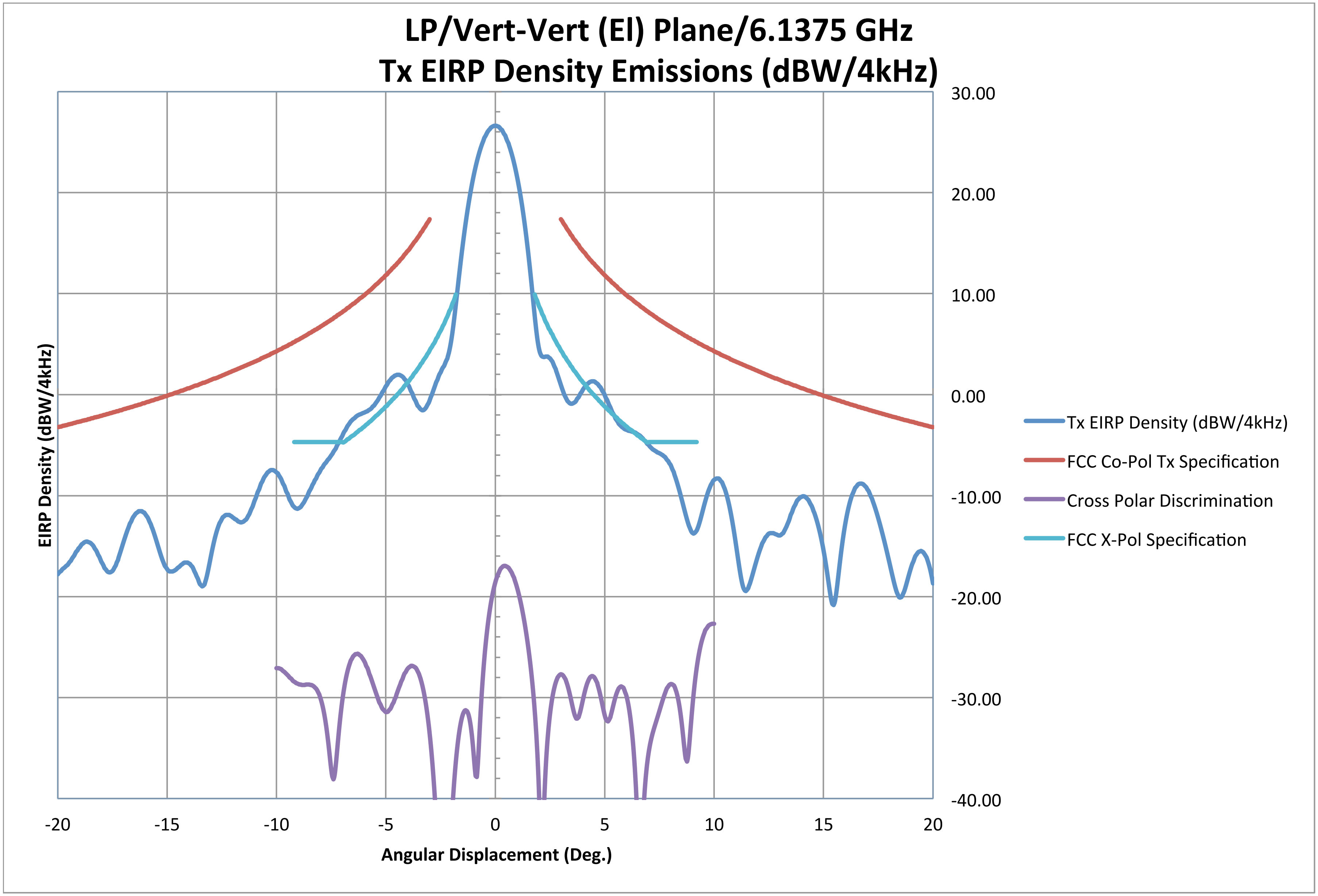
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification



LP/Vert-Vert (El) Plane/6.1375 GHz
Tx EIRP Density Emissions (dBW/4kHz)
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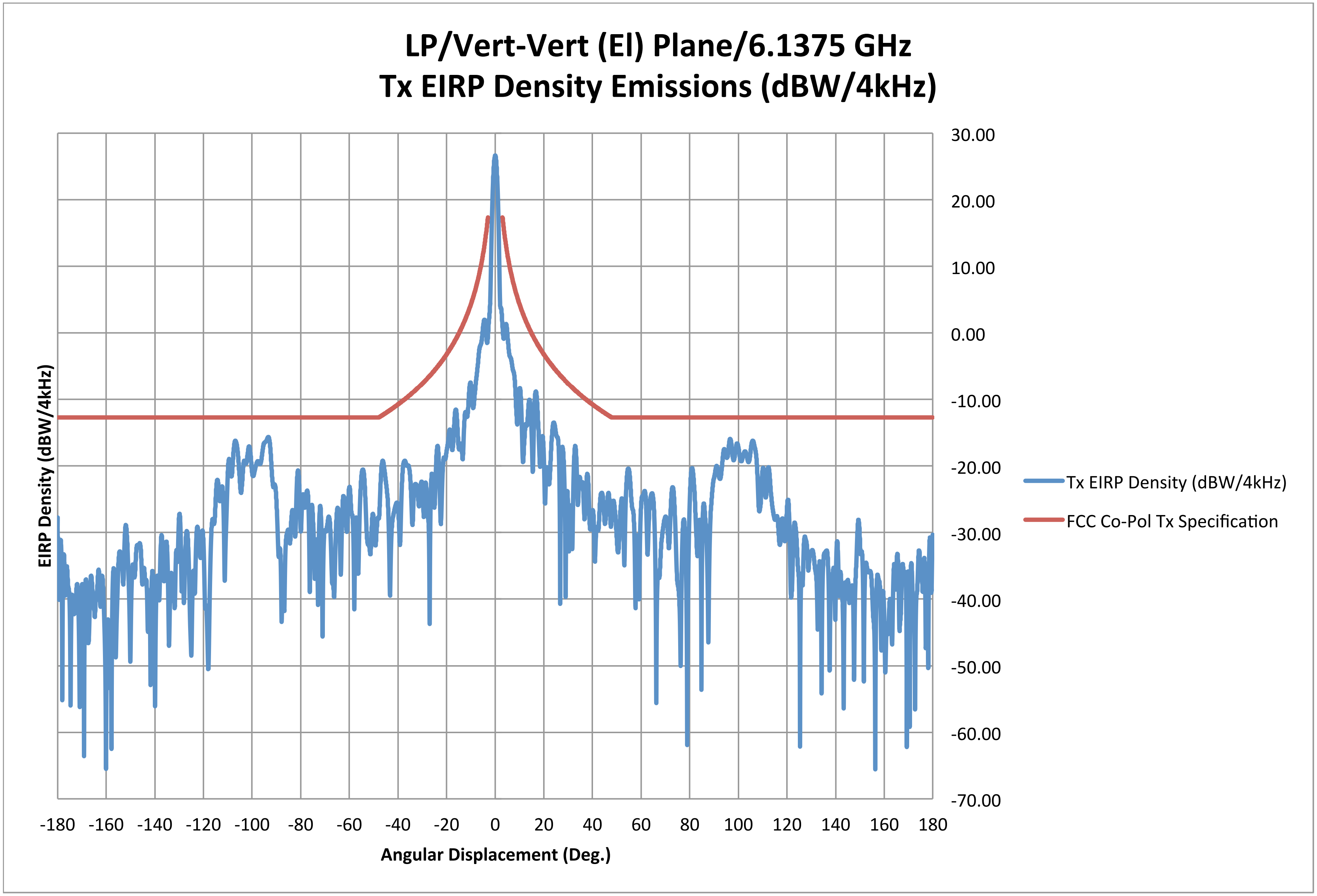
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification
Cross Polar Discrimination
FCC X-Pol Specification


LP/Vert-Vert (El) Plane/6.1375 GHz
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EIRP Density (dBW/4kHz)
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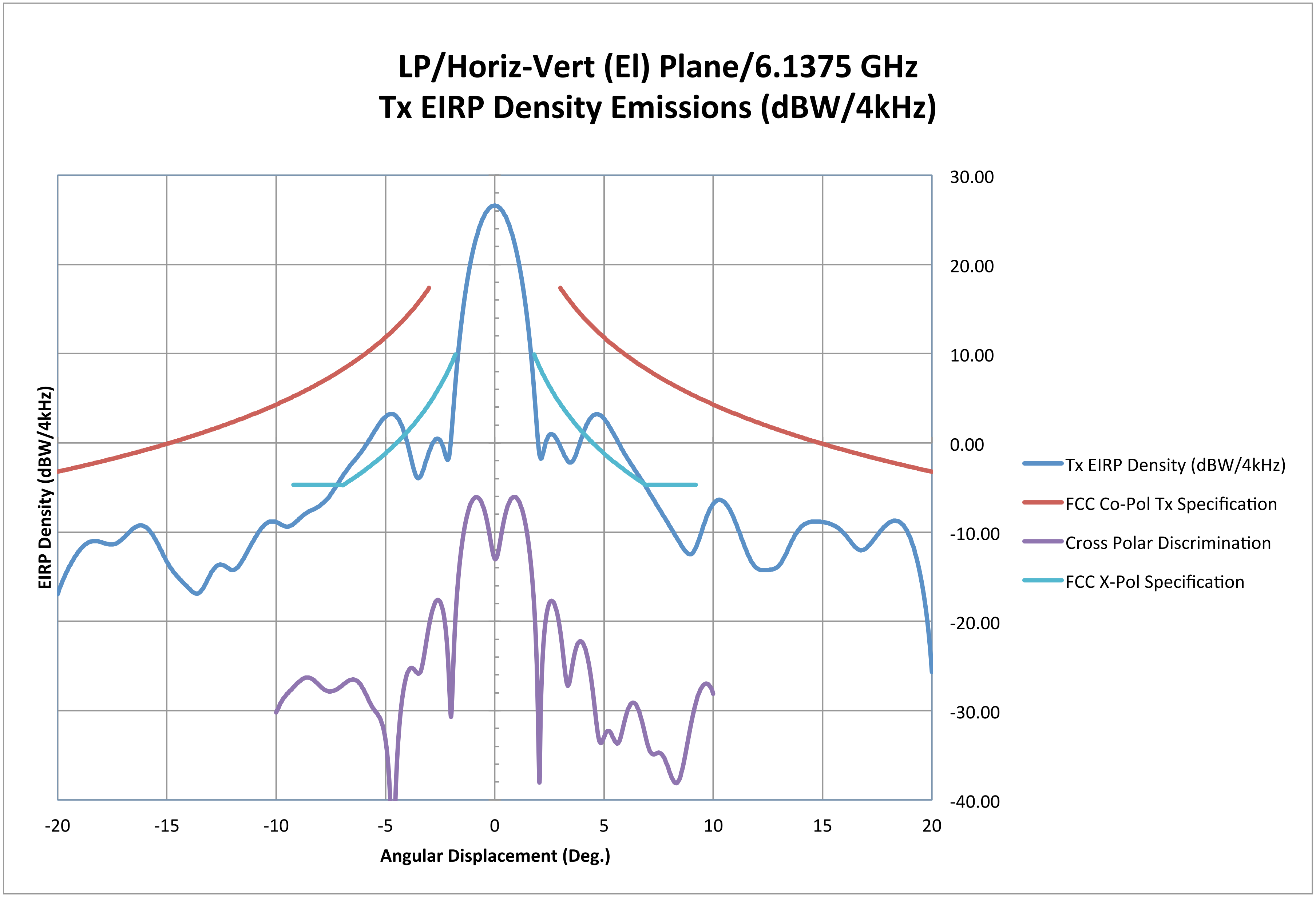
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification



LP/Horiz-Vert (El) Plane/6.1375 GHz
Tx EIRP Density Emissions (dBW/4kHz)
EIRP Density (dBW/4kHz)
Angular Displacement (Deg.)
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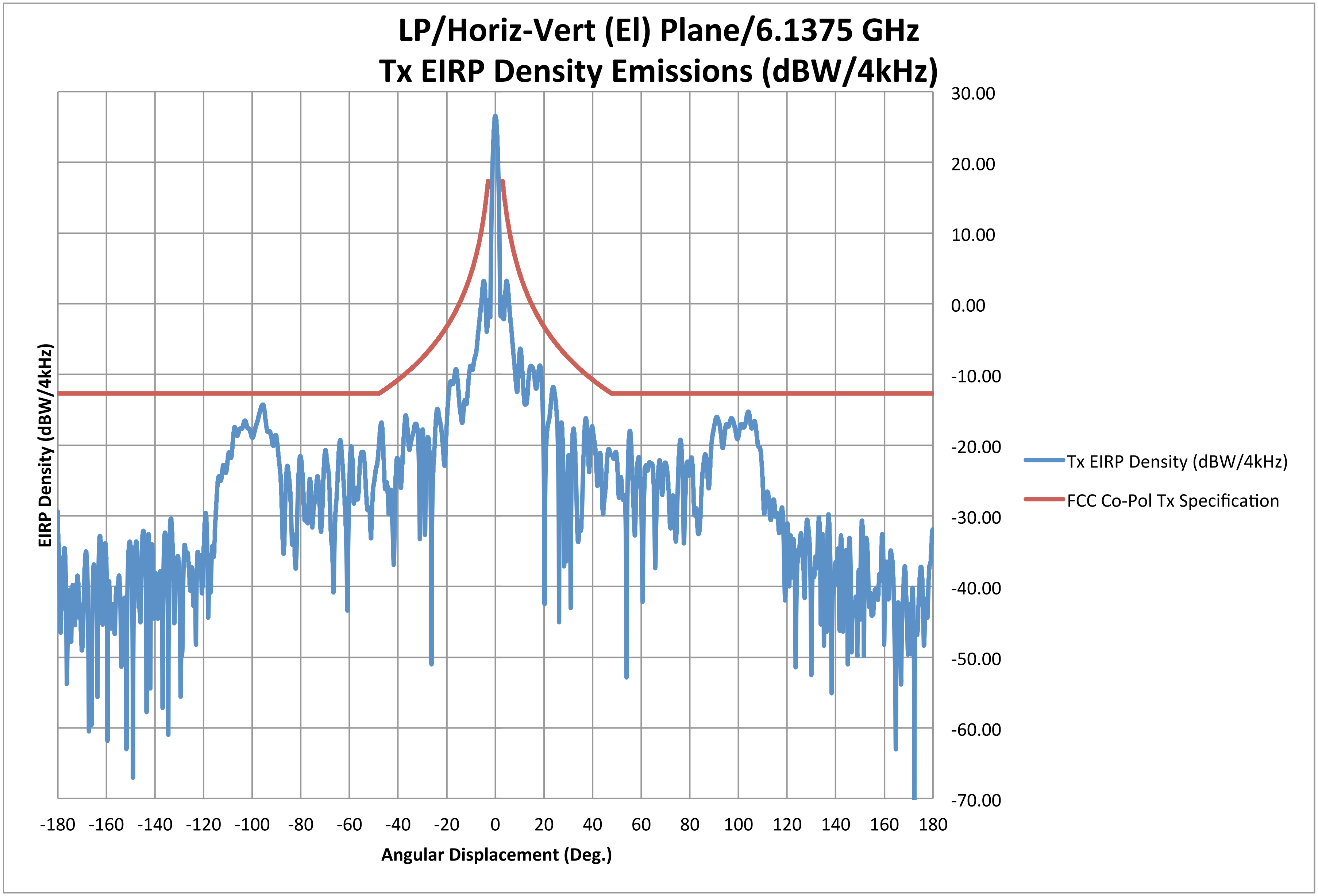
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification
Cross Polar Discrimination
FCC X-Pol Specification



LP/Horiz-Vert (El) Plane/6.1375 GHz
Tx EIRP Density Emissions (dBW/4kHz)
EIRP Density (dBW/4kHz)
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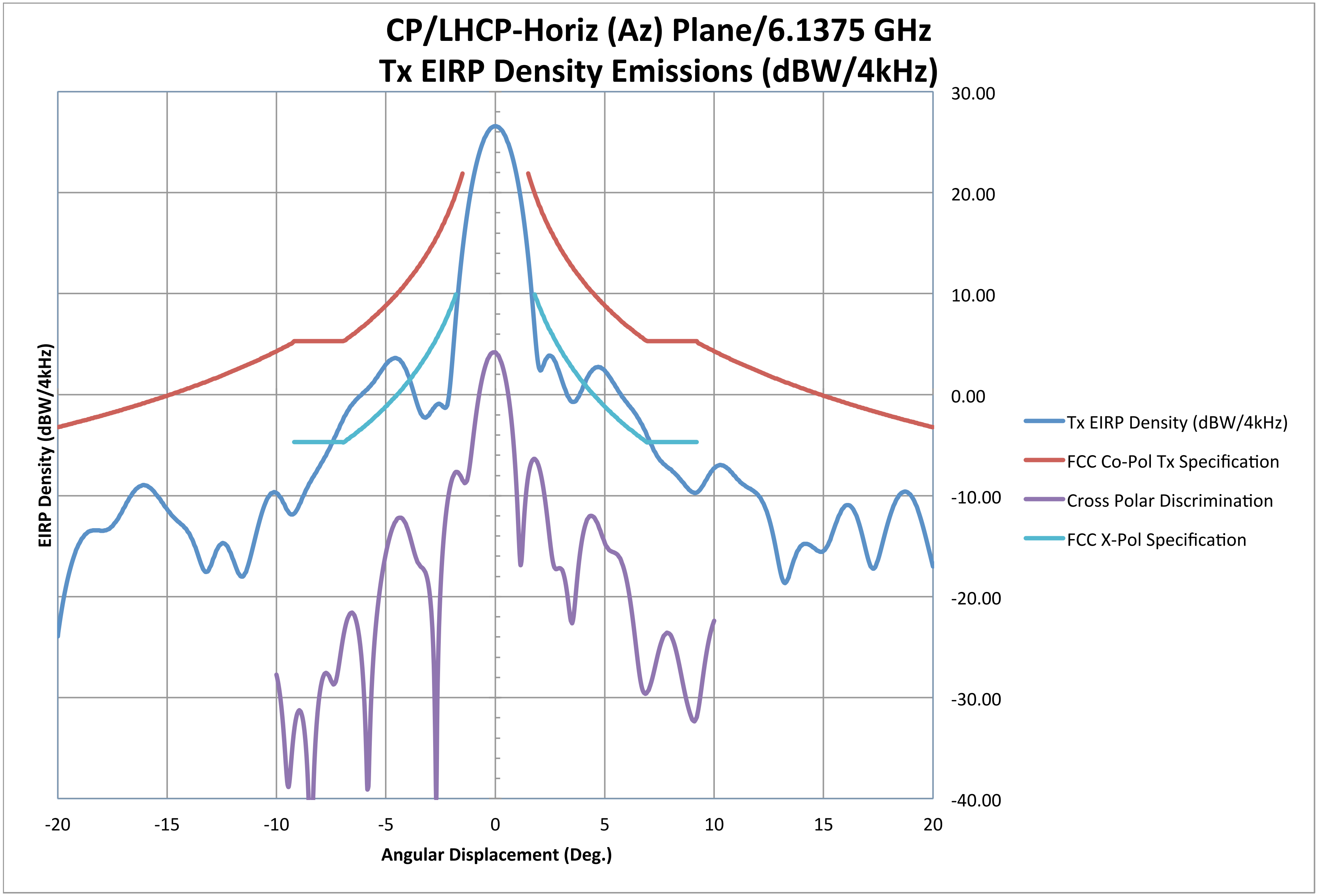
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification



CP/LHCP-Horiz (Az) Plane/6.1375 GHz
Tx EIRP Density Emissions (dBW/4kHz)
EIRP Density (dBW/4kHz)
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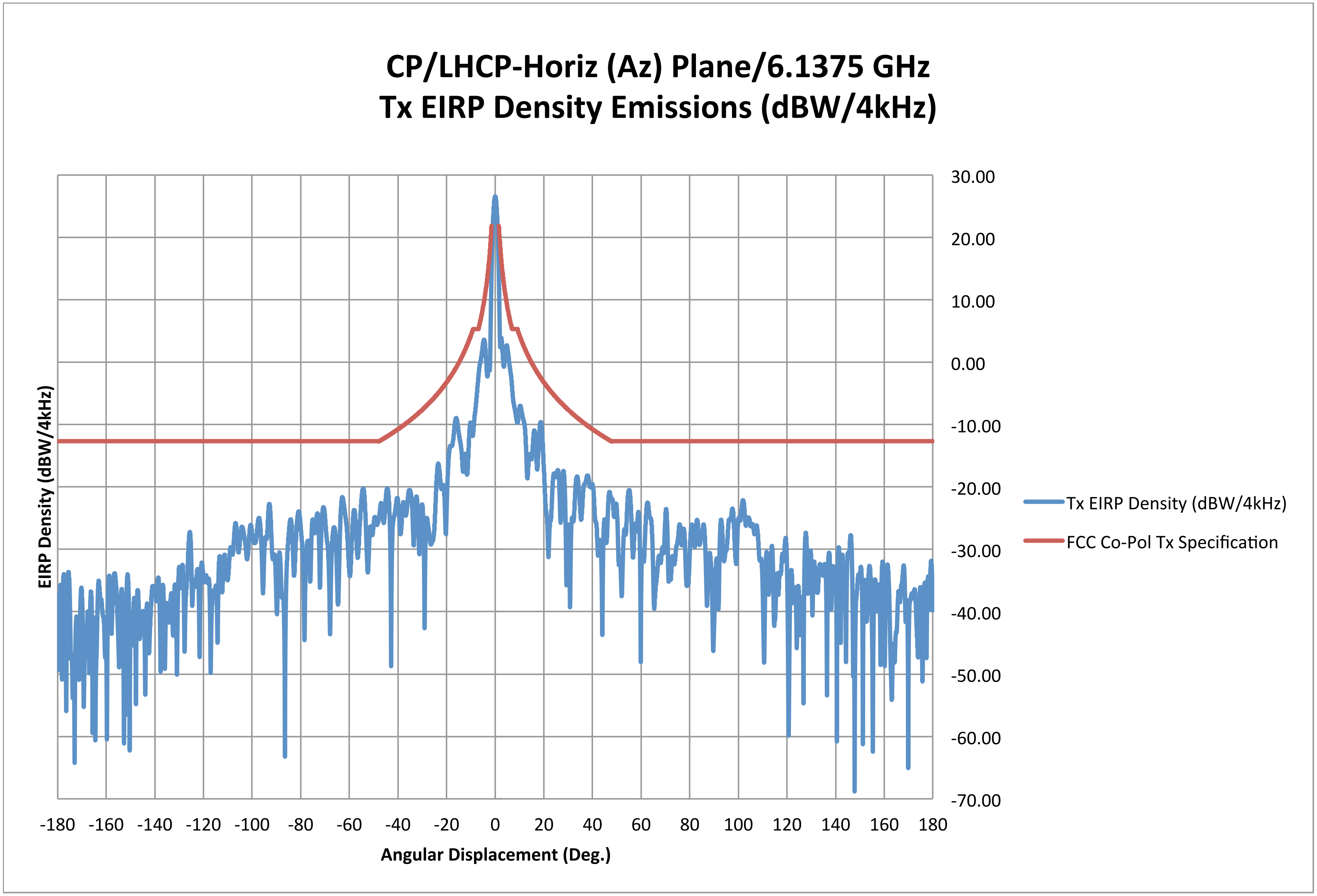
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification
Cross Polar Discrimination
FCC X-Pol Specification



CP/LHCP-Horiz (Az) Plane/6.1375 GHz
Tx EIRP Density Emissions (dBW/4kHz)
EIRP Density (dBW/4kHz)
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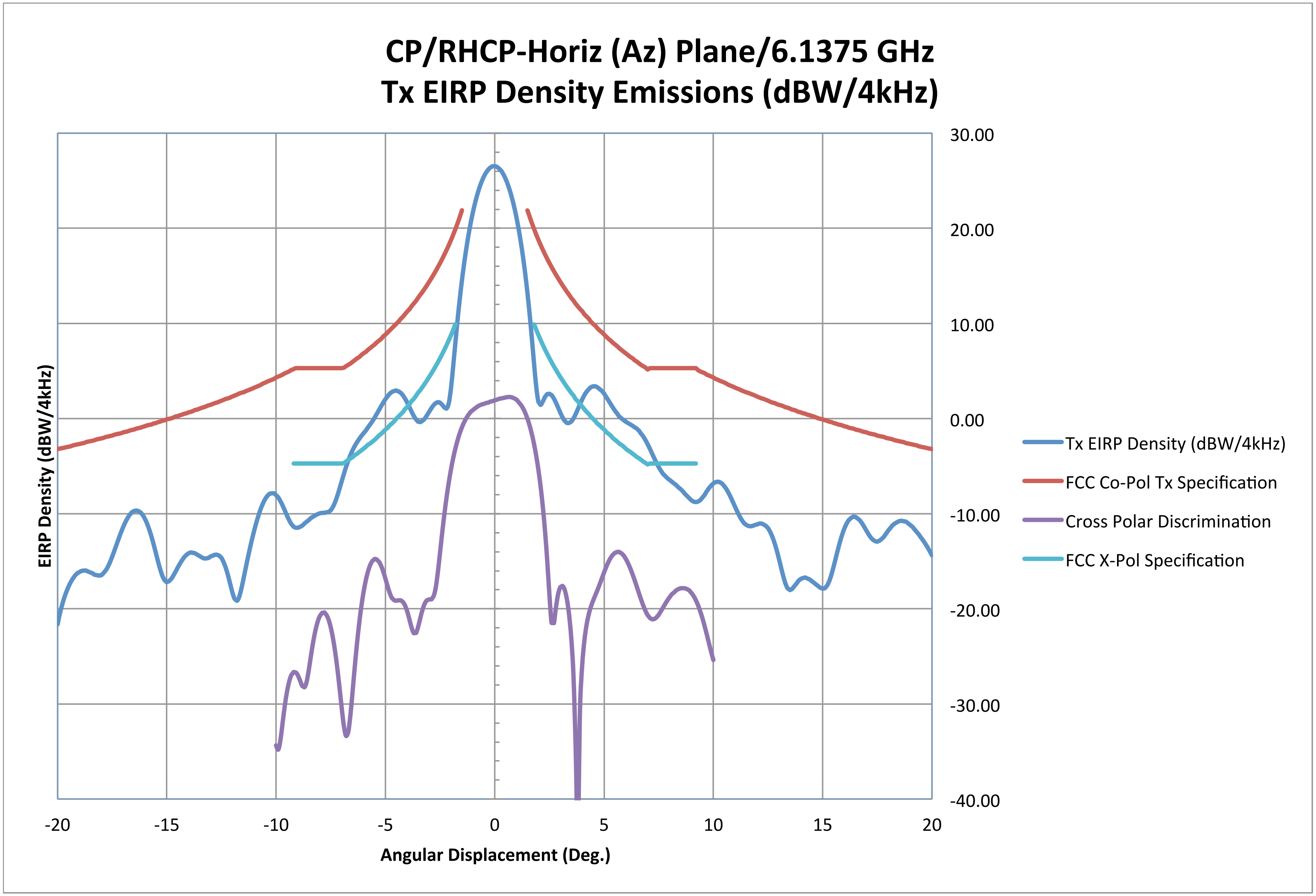
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification



CP/RHCP-Horiz (Az) Plane/6.1375 GHz
Tx EIRP Density Emissions (dBW/4kHz)
EIRP Density (dBW/4kHz)
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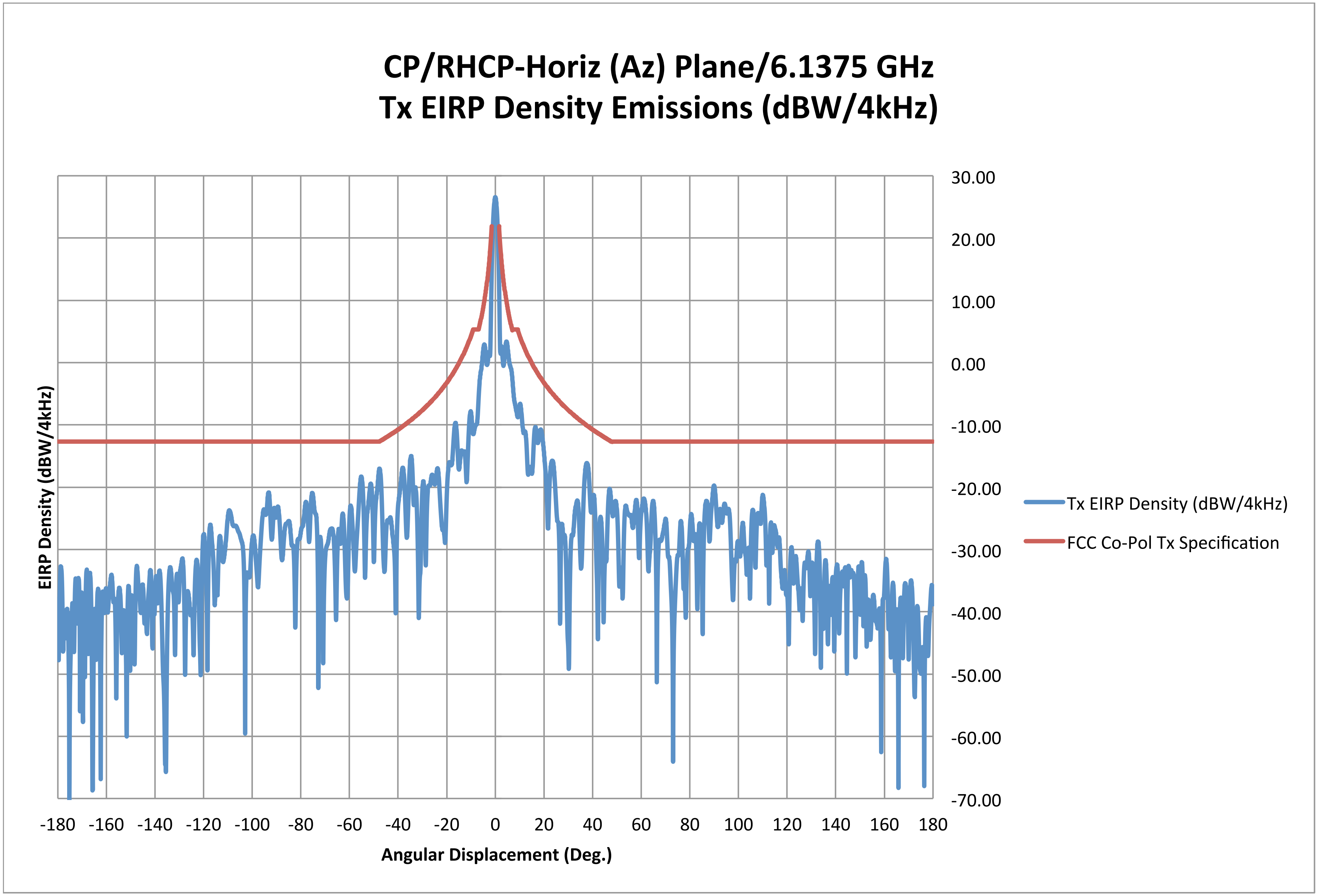
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification
Cross Polar Discrimination
FCC X-Pol Specification



CP/RHCP-Horiz (Az) Plane/6.1375 GHz
Tx EIRP Density Emissions (dBW/4kHz)
EIRP Density (dBW/4kHz)
Angular Displacement (Deg.)
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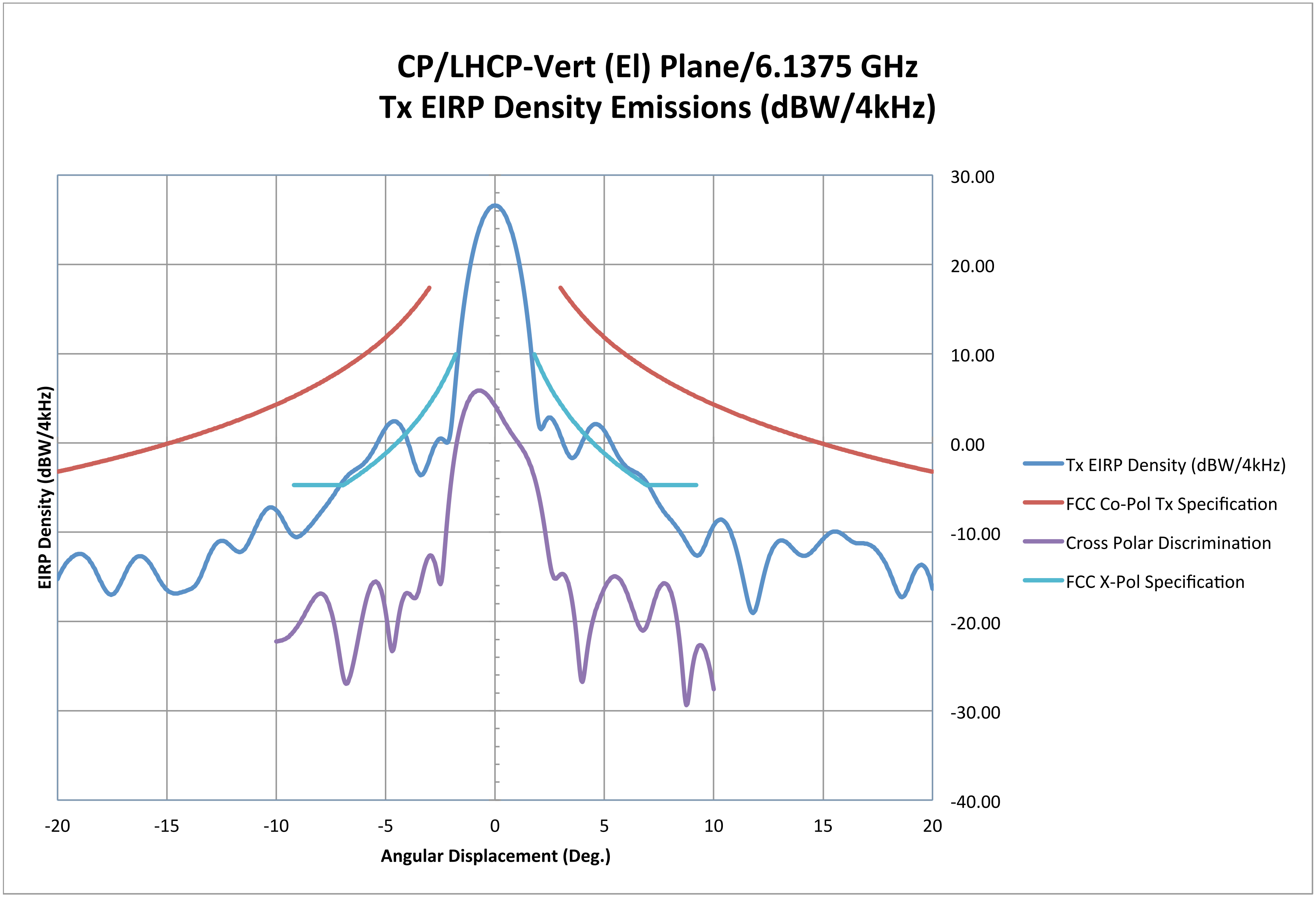
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification



CP/LHCP-Vert (El) Plane/6.1375 GHz
Tx EIRP Density Emissions (dBW/4kHz)
EIRP Density (dBW/4kHz)
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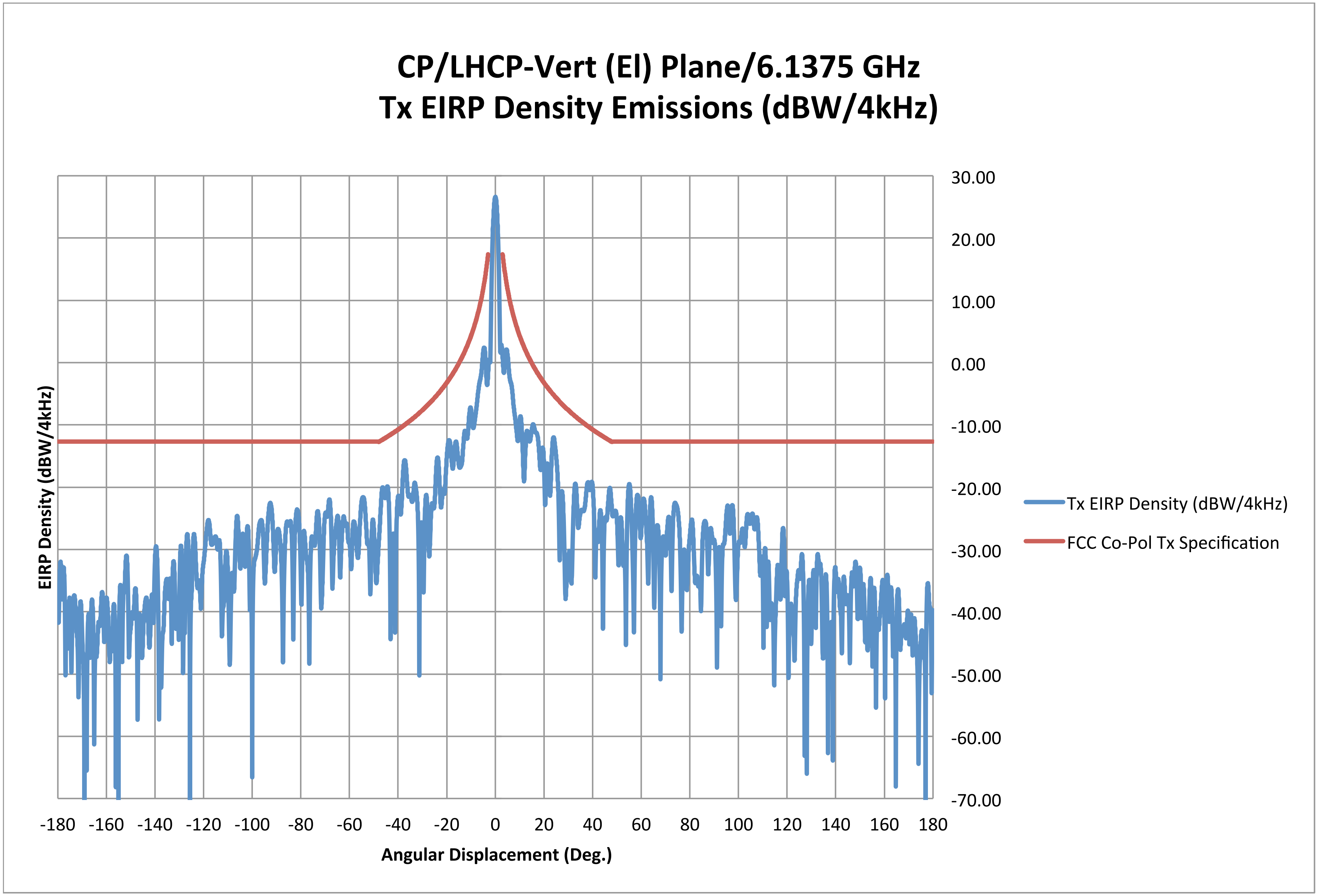
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification
Cross Polar Discrimination
FCC X-Pol Specification


CP/LHCP-Vert (El) Plane/6.1375 GHz
Tx EIRP Density Emissions (dBW/4kHz)
EIRP Density (dBW/4kHz)
Angular Displacement (Deg.)
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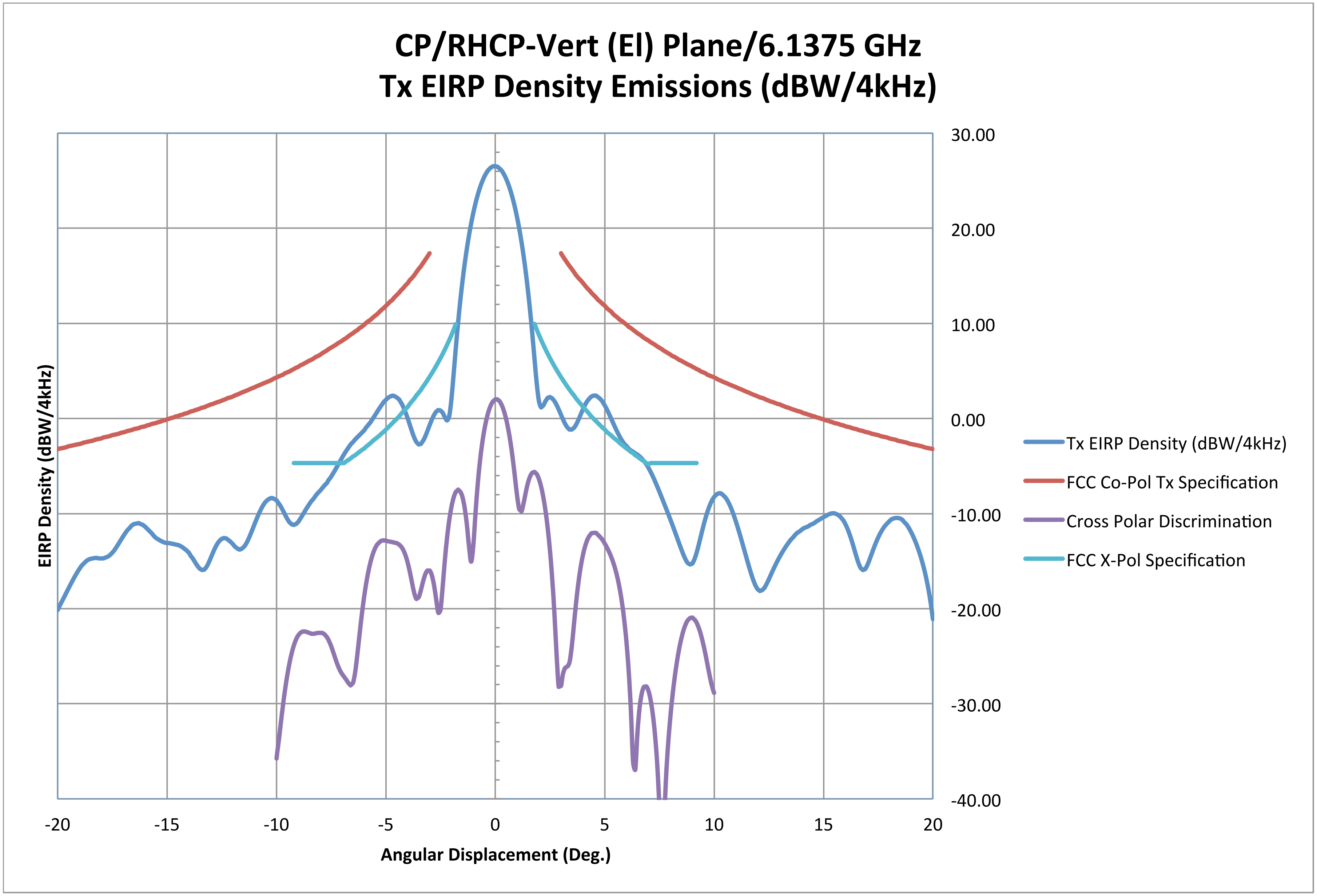
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification



CP/RHCP-Vert (El) Plane/6.1375 GHz
Tx EIRP Density Emissions (dBW/4kHz)
EIRP Density (dBW/4kHz)
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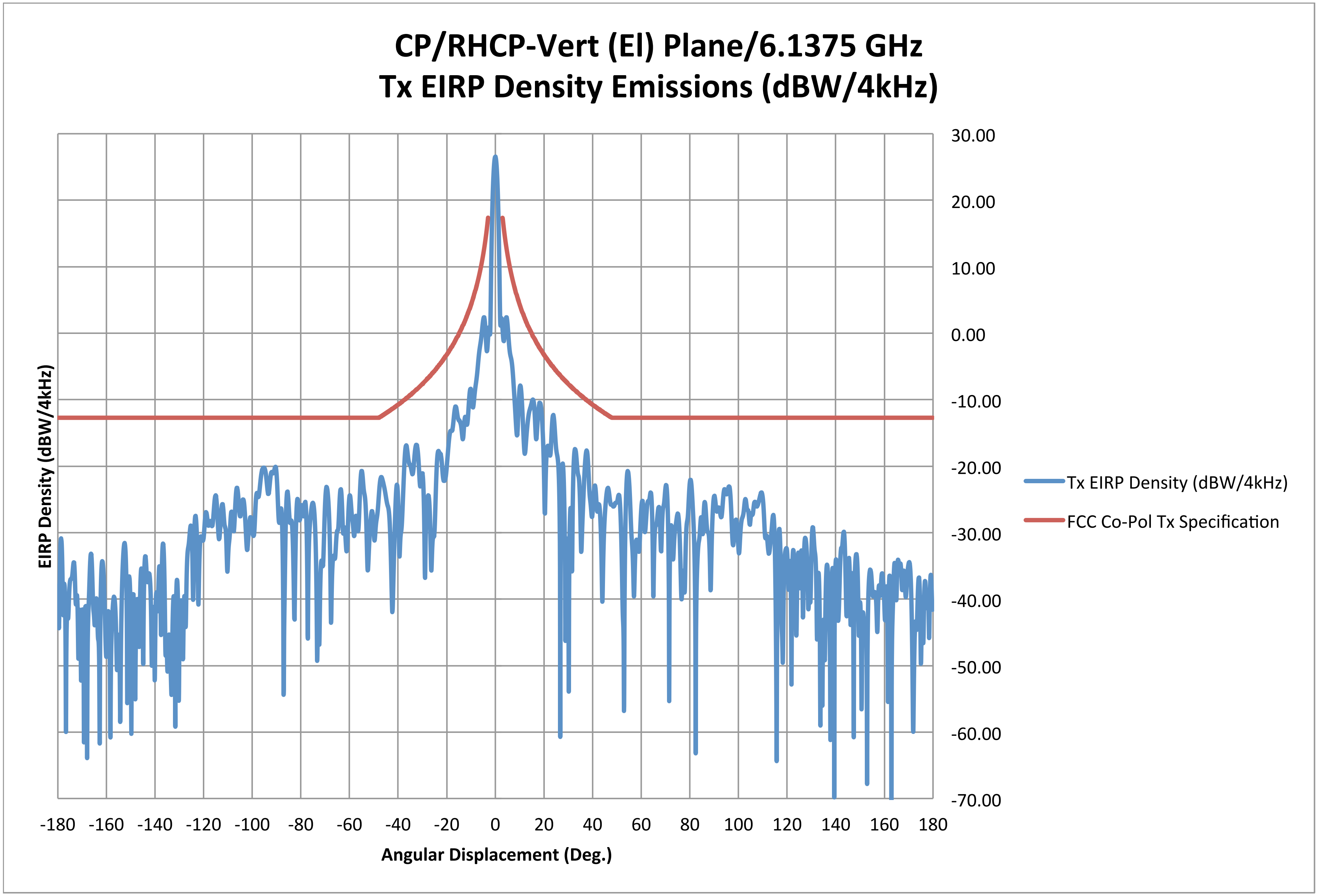
Angular Displacement (Deg.)
Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification
Cross Polar Discrimination
FCC X-Pol Specification



CP/RHCP-Vert (El) Plane/6.1375 GHz
Tx EIRP Density Emissions (dBW/4kHz)
EIRP Density (dBW/4kHz)
Angular Displacement (Deg.)
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Tx EIRP Density (dBW/4kHz)
FCC Co-Pol Tx Specification

Annex 2 – Link Budgets

ST-5000 Antenna Analysis

	Antenna Model	ST 5000 Ku	
	Frequency	14250	Mhz
E41	Antenna Gain (no radome)	43.5	dBi
	Max HPA power	55	W
	Elevation Angle	40.1	°
	Azimuth Angle	124.5	°
	Satellite Longitude	115	°W
	Data Rate	20 to 100	Mbps
	Uplink EIRP	60.49	dBW
	Earth Station Latitute	28.03083333	°N
	Earth Station Longitude	80.59888889	°W
E38	Total Input at the Antenna Flange	50.00	W
E49	Maximum EIRP Density per Carrier	26.51	dBW/4KHz
E48	Maximum EIRP per Carrier	60.49	dBW
E60	Max. EIRP Density towards the Horizon (from elev. Angle)	-25.07	dBW/4KHz
E60	Max. EIRP Density towards the Horizon (if freq. coord.)	-26.99	dBW/4KHz
E40	Total EIRP for all Carriers	60.9	dBW

Emission Designators

1 MHz	1M00G7D
72 MHz	72M0G7D

ST-5000 Antenna Analysis

	Antenna Model	ST 5000 C	
	Frequency	6175	Mhz
E41	**Antenna Gain (no radome)**	38	dBi
	Max HPA power	55	W
	Elevation Angle	56	°
	Azimuth Angle	162.6	°
	Satellite Longitude	89	W
	Data Rate	20 to 100	Mbps
	Uplink EIRP	55.3	dBW
	Earth Station Latitute	28.03083333	°N
	Earth Station Longitude	80.59888889	°W
E38	**Total Input at the Antenna Flange**	53.70317964	W
E49	**Maximum EIRP Density per Carrier**	19.27940009	dBW/4KHz
E48	**Maximum EIRP per Carrier**	55.3	dBW
E60	**Max. EIRP Density towards the Horizon (from elev. Angle)**	-30.4234091	dBW/4KHz
E60	**Max. EIRP Density towards the Horizon (if freq. coord.)**	-28.72059991	dBW/4KHz
E40	**Total EIRP for all Carriers**	55.4	dBW

Emission Designators

1 MHz	1M00G7D
72 MHz	72M0G7D

Annex 3 – Radiation Hazard Study

Radiation Hazard Study

ST5000 C

This study analyzes the potential Radio Frequency (RF) human exposure levels caused by the Electro Magnetic (EM) fields of the above-captioned antenna. The mathematical analysis performed below complies with the methods described in the Federal Communications Commission Office of Engineering and Technology Bulletin No. 65 (1985 rev. 1997) R&O 96-326.

Maximum Permisible Exposure

There are two separate levels of exposure limits. The first applies to persons in the general population who are in an uncontrolled environment. The second applies to trained personnel in a controlled environment. According to 47 C.F.R. § 1.1310, the Maximum Permissible Exposure (MPE) limits for frequencies above 1.5 GHz are as follows:

- General Population / Uncontrolled Exposure 1.0 mW/cm2
- Occupational / Controlled Exposure 5.0 mW/cm2

The purpose of this study is to determine the power flux density levels for the earth station under study as compared with the MPE limits. This comparison is done in each of the following regions:

1. Far-field region
2. Near-field region
3. Transition region
4. The region between the feed and the antenna surface
5. The main reflector region
6. The region between the antenna edge and the ground

Input Parameters

The following input parameters were used in the calculations:

Parameter	Value	Unit	Symbol
Atenna Diameter:	2.4	m	D
Antenna Transmit Gain:	38.00	dBi	G
Trasmit Frequency:	6175	MHz	f
Feed Flange Diameter:	10.00	cm	d
Power Input to the Antenna:	55.00	W	P

Calculated Parameters

The following values were calculated using the above input parameters and the corresponding formulas.

Parameter	Value	Unit	Symbol	Formula
Antenna Surface Area:	4.52	m^2	A	$\pi D^2/4$
Area of Feed Flange:	78.54	cm^2	a	$\pi d^2/4$
Antenna Efficiency:	0.26		η	$G\lambda^2/(\pi^2 D^2)$
Gain Factor:	6309.57		g	$10^{G/10}$
Wavelength:	0.0486	m	λ	$300/f$

Behavior of EM Fields as a Function of Distance

The behavior of the characteristics of EM fields varies depending on the distance from the radiating antenna. These characteristics are analyzed in three primary regions: the near-field region, the far-field region and the transition region. Of interest also are the region between the antenna main reflector and the subreflector, the region of the main reflector area and the region between the main reflector and ground.

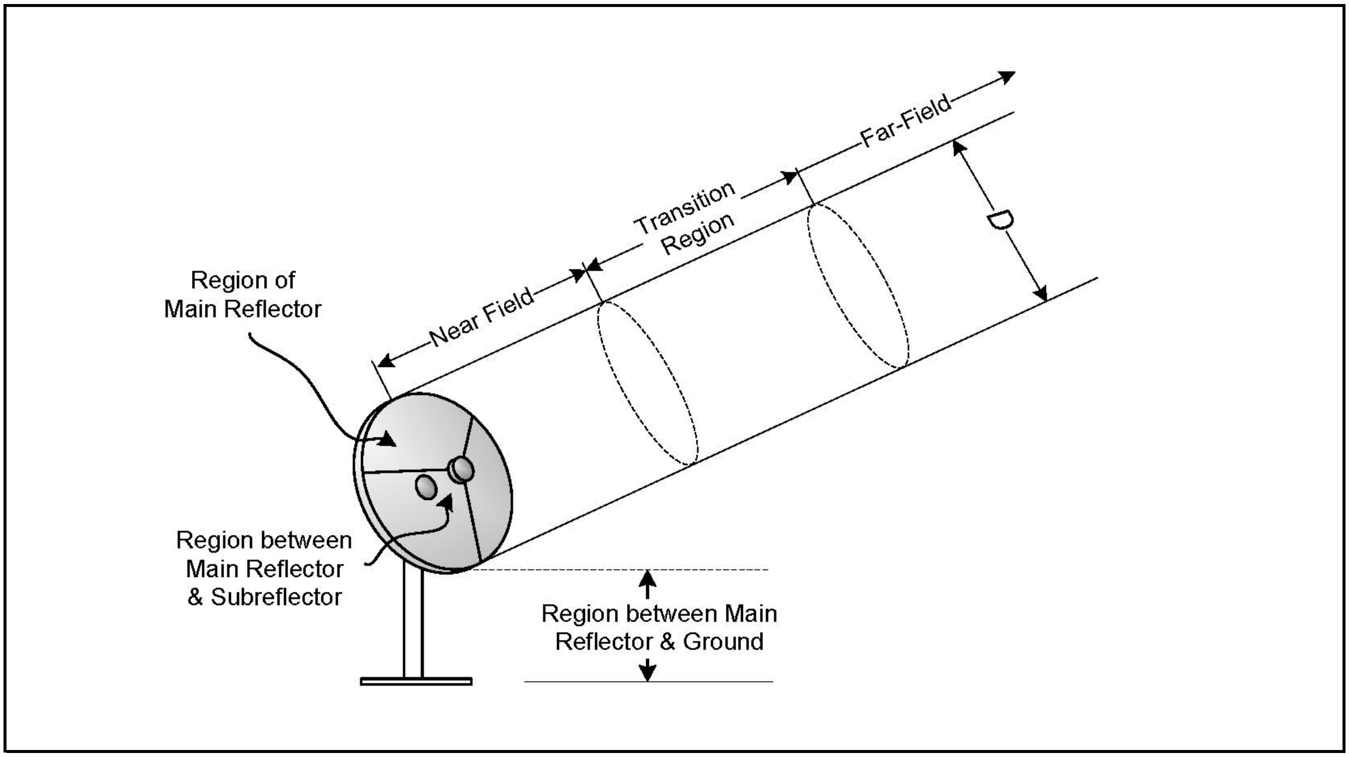

Figure 1. EM Fields as a Function of Distance

For parabolic aperture antennas with circular cross sections, such as the antenna under study, the near-field, far-field and transition region distances are calculated as follows:

Parameter	Value	Unit	Formula
Near Field Distance:	29.640	m	$R_{nf} = D^2/(4\lambda)$
Distance to Far Field:	71.136	m	Rff = 0.60D2/(λ)
Distance of Trasition Region	29.640	m	Rt = Rnf

The distance in the transition region is between the near and far fields. Thus, Rnf ≤ Rt ≤ Rff . However, the power density in the transition region will not exceed the power density in the near-field. Therefore, for purposes of the present analysis, the distance of the transition region can equate the distance to the near-field.

Power Flux Density Calculations

The power flux density is considered to be at a maximum through the entire length of the near-field. This region is contained within a cylindrical volume with a diameter, D, equal to the diameter of the antenna. In the transition region and the far-field, the power density decreases inversely with the square of the distance. The following equations are used to calculate power density in these regions.

Parameter	Value	Unit	Symbol	Formula
Power Density in the Near-Field	1.274	mW/cm^2	S_{nf}	$16.0\ \eta\ P/(\pi D^2)$
Power Density in the Far-Field	0.546	mW/cm^2	S_{ff}	$GP/(4\pi R_{ff}^2)$
Power Density in the Trans. Region	1.274	mW/cm^2	S_t	$S_{nf} R_{nf} / (R_t)$

The region between the main reflector and the subreflector is confined within a conical shape defined by the feed assembly. The most common feed assemblies are waveguide flanges. This energy is determined as follows:

Parameter	Value	Unit	Symbol	Formula
Power Density at the Feed Flange	2801.1	mW/cm^2	S_{fa}	$4P / a$

The power density in the main reflector is determined similarly to the power density at the feed flange; except that the area of the reflector is used.

Parameter	Value	Unit	Symbol	Formula
Power Density at Main Reflector	4.863	mW/cm^2	$S_{surface}$	$4P / A$

The power density between the reflector and ground, assuming uniform illumination of the reflector surface, is calculated as follows:

Parameter	Value	Unit	Symbol	Formula
Power Density between Reflector and Ground	1.216	mW/cm^2	S_g	P / A

Table 1 summarizes the calculated power flux density values for each region. In a controlled environment, the only regions that exceed FCC limitations are shown below. These regions are only accessible by trained technicians who, as a matter of procedure, turn off transmit power before performing any work in these areas.

Power Densities	**mW/cm2**	**Controlled Environment (5 mW/cm2)**
Far Field Calculation	0.546	Satisfies FCC Requirements
Near Field Calculation	1.274	Satisfies FCC Requirements
Transition Region	1.274	Satisfies FCC Requirements
Region between Main and Subreflector	2801.1	Exceeds Limitations
Main Reflector Region	4.863	Satisfies FCC Requirements
Region between Main Reflector and Ground	1.216	Satisfies FCC Requirements

Table 1. Power Flux Density for Each Region

In conclusion, the results show that the antenna, in a controlled environment, and under the proper mitigation procedures, meets the guidelines specified in 47 C.F.R. § 1.1310.

Radiation Hazard Study

ST5000 Ku

This study analyzes the potential Radio Frequency (RF) human exposure levels caused by the Electro Magnetic (EM) fields of the above-captioned antenna. The mathematical analysis performed below complies with the methods described in the Federal Communications Commission Office of Engineering and Technology Bulletin No. 65 (1985 rev. 1997) R&O 96-326.

Maximum Permisible Exposure

There are two separate levels of exposure limits. The first applies to persons in the general population who are in an uncontrolled environment. The second applies to trained personnel in a controlled environment. According to 47 C.F.R. § 1.1310, the Maximum Permissible Exposure (MPE) limits for frequencies above 1.5 GHz are as follows:

- General Population / Uncontrolled Exposure 1.0 mW/cm2
- Occupational / Controlled Exposure 5.0 mW/cm2

The purpose of this study is to determine the power flux density levels for the earth station under study as compared with the MPE limits. This comparison is done in each of the following regions:

1. Far-field region
2. Near-field region
3. Transition region
4. The region between the feed and the antenna surface
5. The main reflector region
6. The region between the antenna edge and the ground

Input Parameters

The following input parameters were used in the calculations:

Parameter	Value	Unit	Symbol
Atenna Diameter:	2.4	m	D
Antenna Transmit Gain:	43.50	dBi	G
Trasmit Frequency:	14250	MHz	f
Feed Flange Diameter:	10.00	cm	d
Power Input to the Antenna:	55.00	W	P

Calculated Parameters

The following values were calculated using the above input parameters and the corresponding formulas.

Parameter	Value	Unit	Symbol	Formula
Antenna Surface Area:	4.52	m^2	A	$\pi D^2/4$
Area of Feed Flange:	78.54	cm^2	a	$\pi d^2/4$
Antenna Efficiency:	0.17		η	$G\lambda^2/(\pi^2 D^2)$
Gain Factor:	22387.21		g	$10^{G/10}$
Wavelength:	0.0211	m	λ	$300/f$

Behavior of EM Fields as a Function of Distance

The behavior of the characteristics of EM fields varies depending on the distance from the radiating antenna. These characteristics are analyzed in three primary regions: the near-field region, the far-field region and the transition region. Of interest also are the region between the antenna main reflector and the subreflector, the region of the main reflector area and the region between the main reflector and ground.

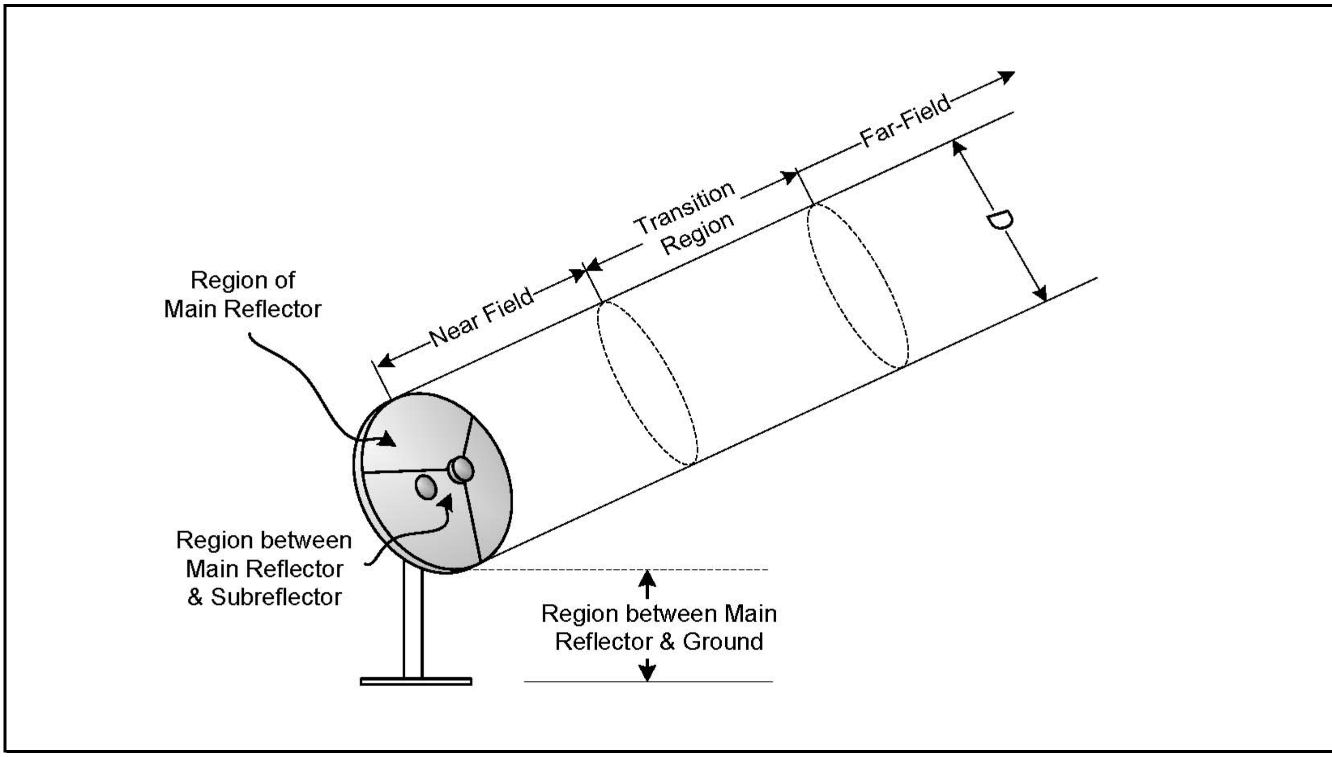

Figure 1. EM Fields as a Function of Distance

For parabolic aperture antennas with circular cross sections, such as the antenna under study, the near-field, far-field and transition region distances are calculated as follows:

Parameter	Value	Unit	Formula
Near Field Distance:	68.400	m	$R_{nf} = D^2/(4\lambda)$
Distance to Far Field:	164.160	m	Rff = 0.60D2/(λ)
Distance of Trasition Region	68.400	m	Rt = Rnf

The distance in the transition region is between the near and far fields. Thus, Rnf ≤ Rt ≤ Rff . However, the power density in the transition region will not exceed the power density in the near-field. Therefore, for purposes of the present analysis, the distance of the transition region can equate the distance to the near-field.

Power Flux Density Calculations

The power flux density is considered to be at a maximum through the entire length of the near-field. This region is contained within a cylindrical volume with a diameter, D, equal to the diameter of the antenna. In the transition region and the far-field, the power density decreases inversely with the square of the distance. The following equations are used to calculate power density in these regions.

Parameter	Value	Unit	Symbol	Formula
Power Density in the Near-Field	0.849	mW/cm^2	S_{nf}	$16.0\ \eta\ P/(\pi D^2)$
Power Density in the Far-Field	0.364	mW/cm^2	S_{ff}	$GP/(4\pi R_{ff}^2)$
Power Density in the Trans. Region	0.849	mW/cm^2	S_t	$S_{nf}\ R_{nf}\ /(R_t)$

The region between the main reflector and the subreflector is confined within a conical shape defined by the feed assembly. The most common feed assemblies are waveguide flanges. This energy is determined as follows:

Parameter	Value	Unit	Symbol	Formula
Power Density at the Feed Flange	2801.1	mW/cm^2	S_{fa}	$4P\ /\ a$

The power density in the main reflector is determined similarly to the power density at the feed flange; except that the area of the reflector is used.

Parameter	Value	Unit	Symbol	Formula
Power Density at Main Reflector	4.863	mW/cm^2	$S_{surface}$	$4P\ /\ A$

The power density between the reflector and ground, assuming uniform illumination of the reflector surface, is calculated as follows:

Parameter	Value	Unit	Symbol	Formula
Power Density between Reflector and Ground	1.216	mW/cm^2	S_g	$P\ /\ A$

Table 1 summarizes the calculated power flux density values for each region. In a controlled environment, the only regions that exceed FCC limitations are shown below. These regions are only accessible by trained technicians who, as a matter of procedure, turn off transmit power before performing any work in these areas.

Power Densities	**mW/cm2**	**Controlled Environment (5 mW/cm2)**
Far Field Calculation	0.364	Satisfies FCC Requirements
Near Field Calculation	0.849	Satisfies FCC Requirements
Transition Region	0.849	Satisfies FCC Requirements
Region between Main and Subreflector	2801.1	Exceeds Limitations
Main Reflector Region	4.863	Satisfies FCC Requirements
Region between Main Reflector and Ground	1.216	Satisfies FCC Requirements

Table 1. Power Flux Density for Each Region

In conclusion, the results show that the antenna, in a controlled environment, and under the proper mitigation procedures, meets the guidelines specified in 47 C.F.R. § 1.1310.