RF Unit Clearances

ISSUING DIVISION: Electric Engineering **Signed by** *Orville J. Plum*
SVP SPONSOR: Orville Plum, Manager **Date Signed** October 6, 2011

SECTION: Clearances SD 1275

Scope of Standard

This document defines the RF units deployed in SVP territory and its specifications. Standard regulation, identification, compliance boundaries, safety procedures, and guidelines are discussed.

Purpose of Revision

With the increasing dependence on wireless communication, exposure limits and compliance boundaries must be carefully examined and followed as to assure no harmful exposure will compromise the health of workers and the surrounding public. Since the RF units in SVP territory are mounted onto streetlights and poles, it is important to identify what kinds of units are being deployed and what precautions should be taken when maintenance or other work is needed around the area. Identification, compliance with other clearances, and standard operational procedure are essential components that must be addressed and followed.

References

- "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz - Amendment 1: Specifies Ceiling Limits for Induced and Contact Current, Clarifies Distinctions between Localized Exposure and Spatial Peak Power Density," *IEEE Std C95.1a-2010 (Amendment to IEEE Std C95.1-2005)* , vol., no., pp.C1-9, March 16 2010 doi: 10.1109/IEEESTD.2010.5433227
- "IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields With Respect to Human Exposure to Such Fields,100 kHz-300 GHz," *IEEE Std C95.3-2002 (Revision of IEEE Std C95.3-1991)* , vol., no., pp.i-126, 2002 doi: 10.1109/IEEESTD.2002.94226
- Evaluating Compliance with FCC. Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields. **OET** Bulletin **65**. Edition 97-01. August 1997.
- Questions and Answers about Biological Effects and Potential Hazards or Radiofrequency Electromagnetic Waves. OET Bulletin 56. Fourth Edition. August 1999.
- Rules for Overhead Electric Line Construction. General Order No. 95. Public Utilities Commission of the State of California. January 2006.
- Joint Pole Routine Handbook. Northern California Joint Pole Association. 2010.
- "Assessment of Human Exposure to Electromagnetic Radiation from Wireless Devices in Home and Office Environments" Sven Kühn, Urs Lott, Axel Kramer, Niels Kuster. Foundation for Research on Information Technologies in Society. ETH Zurich, Switzerland.

Rescissions

None – This is an original document that has not been previously issued by the SVP Electrical Engineering Division.

Definition of Terms

- **ANTENNA:** That part of a transmitting or receiving system that is designed to radiate or to receive electromagnetic waves.
- **AVERAGING TIME:** Time period a person can be exposed to emissions at the SAR threshold; averaging time for controlled and uncontrolled exposure are 6 and 30 minutes, respectively.
- **COMPLIANCE BOUNDARY:** Minimum distance in all directions from the transmitting antenna at which the exposure is still within MPE limits.
- **CONTROLLED CONDITIONS:** For FCC purposes, applies to human exposure to RF fields when persons are exposed as a consequence of their employment and in which those persons who are exposed have been made fully aware of the potential for exposure and can exercise control over their exposure. Occupational/controlled exposure limits also apply where exposure is of a transient nature as a result of incidental passage through a location where exposure levels may be above general population/uncontrolled limits (see definition above), as long as the exposed person has been made fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.
- **DIRECTIONAL ANTENNA:** Radiates power more effectively in one direction than in others.
- **FCC:** Federal Communications Commission established by the Communications Act of 1934 to regulates communications by radio, television, wire, satellite and cable in all 50 states, the District of Columbia and U.S. territories**.**
- **FIXED INSTALLATION:** Fixed location means that the device, including its antenna, is physically secured at a permanent location and is not able to be easily moved to another location.
- **GAIN:** Maximum increase in intensity of an antenna relative to a hypothetical ideal antenna radiating equally in all directions without loss; usually expressed in dB_i; The ratio, usually expressed in decibels, of the power required at the input of a loss-free reference antenna to the power supplied to the input of the given antenna to produce, in a given direction, the same field strength or the same power density at the same distance. When not specified otherwise, the gain refers to the direction of maximum radiation. Gain may be considered for a specified polarization. Gain may be referenced to an isotropic antenna (dBi) or a half-wave dipole (dBd).
- **ICNIRP:** International Commission on Non-ionizing Radiation Protection; commission brought to bear on addressing the important issues of possible adverse effects on human health of exposure to non-ionizing radiation.
- **IEEE:** Institute of Electrical and Electronics Engineers; the world's largest

professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through IEEE's highly cited publications, conferences, technology standards, and professional and educational activities.

- **MOBILE DEVICE:** A transmitting device designed to be used in other than fixed locations and to be generally used in such as way that a separation distance of at least 20 cm is normally maintained between the transmitters' radiating structures and the body of the user or nearby persons. Transmitters designed to be used by consumers or workers that can be easily re-located are considered mobile devices if they meet the 20 cm separation requirement.
- **MPE:** Maximum permissible exposure; highest level of exposure that defines the limit between safe and harmful exposure; The RMS and peak electric and magnetic field strength, their squares, or the plane-wave equivalent power densities associated with these fields to which a person may be exposed without harmful effect and with an acceptable safety factor.
- **OMNI-DIRECTIONAL ANTENNA:** Radiates power uniformly in all directions.
- **PORTABLE DEVICE:** A transmitting device designed to be used so that the radiation structure(s) of the device is/are within 20 cm of the body of the use.
- **POWER DENSITY:** Amount of power per unit volume radiated from a transmitting antenna in W/m^2 or mW/cm^2.
- **RF:** Radio frequency; refers to any frequency within the electromagnetic spectrum associated with radio wave propagation (3 kHz – 300 GHz). When an RF current is supplied to an antenna, an electromagnetic field is created that then is able to propagate through space. Many wireless technologies are based on RF field propagation.
- **SAR:** Specific absorption rate; measure of the rate of energy absorbed by the body in W/kg; guidelines for human exposure to RF fields are based on SAR thresholds where adverse biological effects may occur.
- **STANDARD OPERATIONAL PROCEDURE:** A set of written instructions that document proper work practices to ensure compliance with regulations
- **TRANSMITTER POWER:** Maximum power emitted from an antenna expressed in dB_m.
- **UNCONTROLLED CONDITIONS:** For FCC purposes, applies to human exposure to RF fields when the general public is exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure. Therefore, members of the general public always fall under this category when exposure is not employment-related.

Introduction

Wireless communication continues to become a critical necessity in the communications industry and will continue to advance as new products provide high-speed high-quality information exchange. These types of communication, such as cell phones, gas meters, and wireless routers, are designated certain frequency ranges and have a corresponding power density and specific absorption rate (SAR) limit that regulates the amount of exposure absorbed by the human body. Whole body and local (partial) body SAR limits are given for both workers and the general public per FCC and IEEE Std C95.1-2005 Section 4.2.

	SAR Limits			
Exposure Type	**Whole Body**	**Local (Head/Trunk)**		**Local (Limbs)**
		1 g	**10 g**	
Controlled/Worker	0.4 W/kg	8	10 W/kg	20 W/kg
Uncontrolled/Public	0.08 W/kg	1.6 W/kg	2 W/kg	4 W/kg

Note: Local limits apply to exposure averaged over 10g of tissue (unless otherwise specified).

Table 1 – SAR Limits for 100 kHz – 6 GHz

SAR values
AirPort Extreme Wifi Station: 0.06 W/kg (>10g)
Apple iPhone 4: 1.17 W/kg (at ear)
Motorola Droid 2 Global: 1.58 W/kg (at ear)

SAR values are measures of the absorption rate of the body and are used to evaluate portable devices such as cell phones or any device that is designed to be used with 20 cm of the user's body. Mobile devices, such as "bag" telephones and devices with vehicle-mounted antennas, are designed to be used such that a distance of at least 20 cm is maintained between the transmitter and the user's body. These devices, along with fixed installation devices (devices that are physically secured at a permanent location and cannot be easily moved) are evaluated with respected to power density and MPE limits, which are derived from the SAR limits. The magnitude of power density at a location is inversely proportional to the distance between the antenna and location. In other words, the farther away you are from the antenna, the smaller the power density is. Power density is be measured in W/m^2 or mW/cm^2, where 10 W/m^2 = 1 mW/cm^2**.**

In order to prevent RF overexposure and make antennas inaccessible to the general public, restrictive measures are taken such as mounting antennas on supporting towers or fencing off antenna sites. For workers who are required to work closer to the antenna, however, other precautions must be made. RF units in SVP territory that are mounted onto streetlights and power poles must demonstrate compliance with governmental regulations as to ensure the safety of workers and general public.

FCC Regulation Limits

The IEEE Std C95.1-2005 and FCC have a safety standard for evaluating human exposure to RF emission which includes limits for Maximum Permissible Exposure (MPE) based on electric and magnetic field strength, power density, and transmitting frequency of the emitting device. Limits are defined for controlled and uncontrolled conditions. All values apply whether radiation is continuous or periodic. If the periodic transmission rate is known, the MPE limit can be divided by the duty factor or following formula to find the correct power density limit:

(# transmissions per averaging time) x (transmit interval per transmission) **Calc. 1**

For example, a 900MHz RF unit has a power density of 3mW/cm^2. If a 50% duty cycle is known, the controlled power density limit would be 3 / 0.50 = 6mW/cm^2.

Frequency Range (MHz)	Power Density (mW/cm^2)	Whole Body SAR (W/kg)	Averaging Time (min)
30-300	1.0	0.4	6
300-1500	f/300	0.4	6
1500-100,000	5	0.4	6

Table 2 – Limits for Controlled Exposure

Frequency Range (MHz)	Power Density (mW/cm^2)	Whole Body SAR (W/kg)	Averaging Time (min)
30-300	0.2	0.08	30
300-1500	f/1500	0.08	30
1500-100,000	1.0	0.08	30

Table 3 – Limits for Uncontrolled Exposure

Note: The averaging time is the maximum period for exposure to the corresponding power density limit. This also means that time averaging is applicable towards exposure at a different power density. For example, a controlled worker can be exposed to twice the power density limit for 3 minutes as long as the worker was not exposed at all in the preceding and following 3 minutes.

Figure 1 describes the Tropos gatekeeper and mesh router frequencies with their corresponding power density requirements. The mesh router includes 2 types of antennas at different frequencies. These values are applicable to a variety of antennas. For other cases, the values signify the *worst case* prediction of the field.

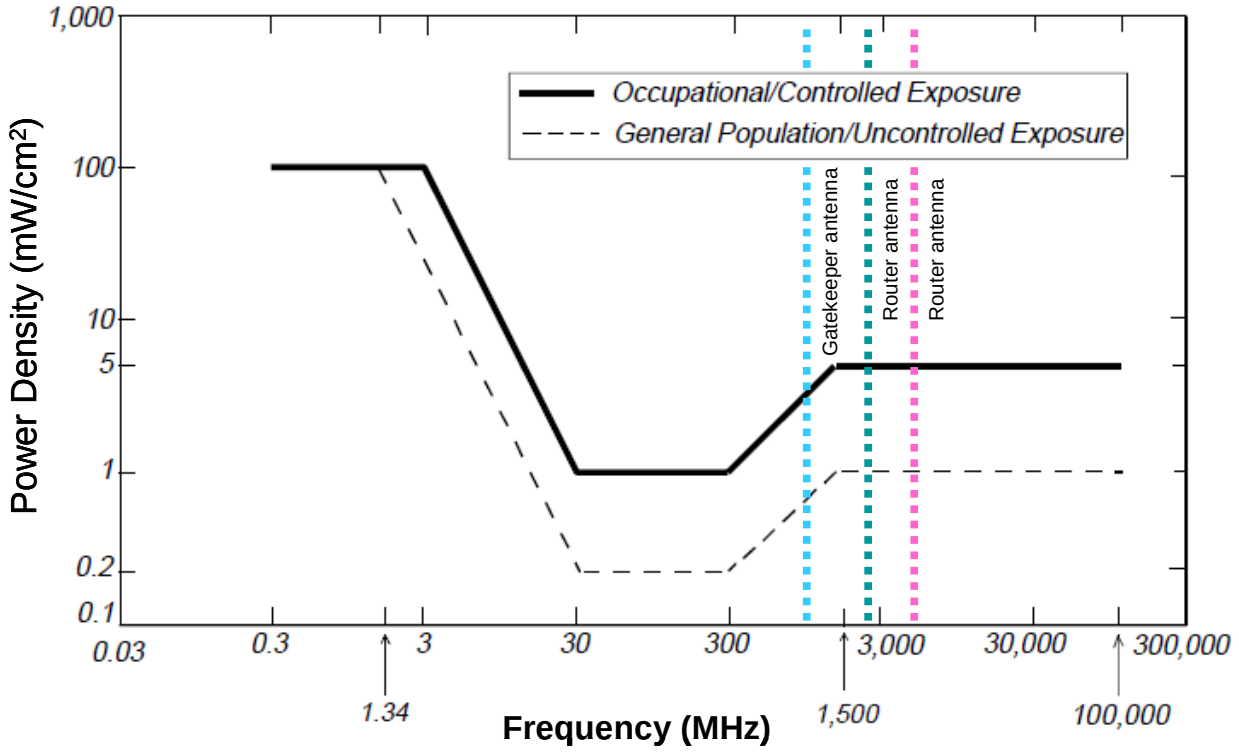


Figure 1 – Power Density vs. Frequency

MPE Limits

The distance *r* at maximum permissible exposure can be found by deriving the power density equation using the power density limit from Table 2 or Table 3 and the specifications of the antenna:

$$S = \frac{P \times G}{4\pi r^2} \quad W/m^2 \qquad \textbf{Calc. 2}$$

$$r = [(30 \times P \times G) / (377 \times S)]^{\frac{1}{2}} \quad \text{meters} \qquad \textbf{Calc. 3}$$

Where:

S = Power Density (W/m^2)
P = Transmitted Power (W)
G = Gain
r = MPE distance (m)

Note: To convert from dB_m to watts, use $W = 10^{(dBm/10)-3}$
To convert gain from dB_i to a unitless figure, use $dB_i = 10^{(dBi/10)}$

Radiation Pattern

The SkyPilot Extender consists of 8 directional antennas that make up 360° coverage (45° azimuth each). The data collection unit and SkyPilot Connector also use a directional antenna. All other devices have omni-directional antennas such that energy is transmitted equally in all directions. Figure 2 illustrates the two radiation patterns. The antenna is shaded in gray.

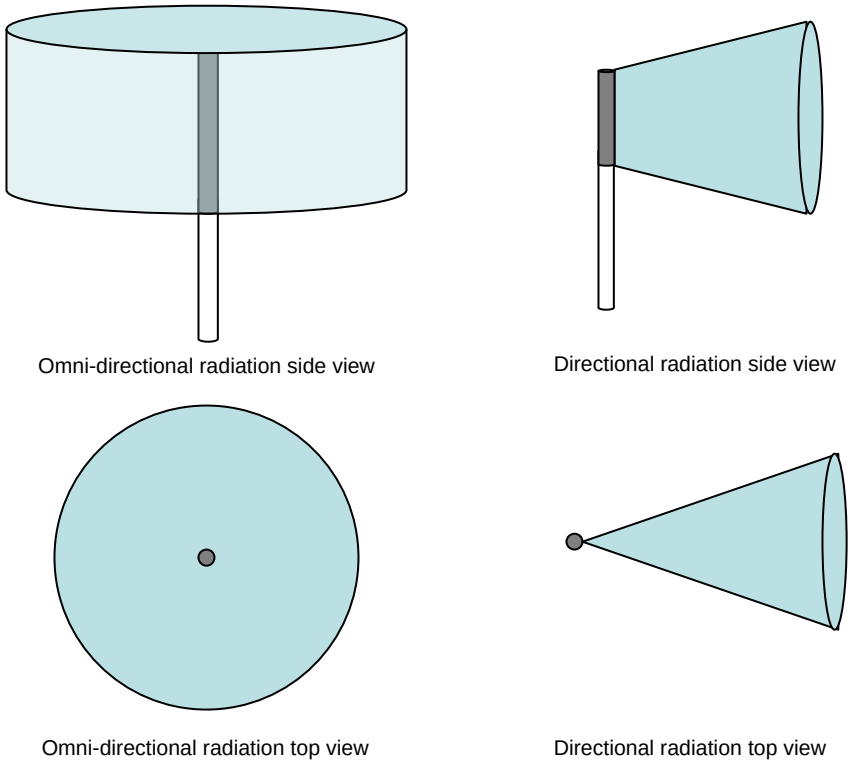


Figure 2 Radiation Patterns

Physical Mounting and Connections

The SVP Tropos 7320 routers and SkyPilot Extenders are mounted at the arms the street lights through hose clamps as shown in the left side of Figure 2. The unit is powered by the AC power adapter on the photo sensor. PG&E data collection units are also mounted on street lights such that the 462 MHz and 467 MHz whip antennas are placed in parallel to the pole as illustrated in Figure 3.

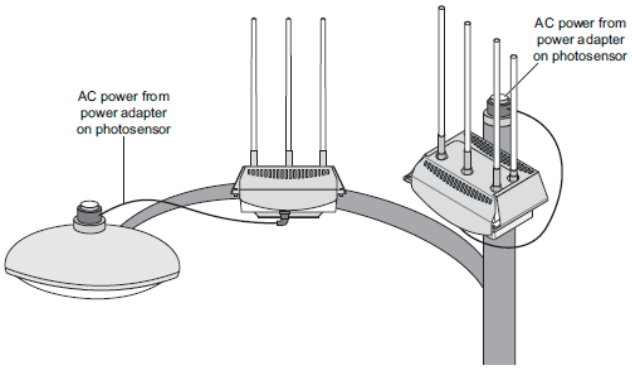


Figure 3 – Tropos 7320 Router and DCU Physical Mounting

Antenna Specifications

Type	Owner	Freq.	Model No.	Max Gain (dB_i)	Max Power Output (dB_m)	MPE Dist.		FCC ID
						cm	in	
Mesh Router	SVP	2.4 GHz	TRIDENT	7.4	28.5	17.4	6.85	P9J-2411
Mesh Router	SVP	5.8 GHz	SPEAR	8	26.4	14.8	5.83	P9J-5805
Gatekeeper	SVP	900 MHz	-	5.64	24	4.3	4.33	QZC - ILC2
SP Connector	SVP	5.8 GHz	-	16.30	30	58.3	22.9	RV7-SC6000
SP Extender	SVP	5.8 GHz	-	18	30	70.9	27.9	RV7-SD1085
MTU	PG&E	467 MHz	-	0	28.10	20	8	LLB09010B
DCU	PG&E	838 MHz	-	-	26.22	20	8	O9EQ2438F-M
DCU	PG&E	462 MHz	-	-	32.50	20	8	LLB9975J

Table 4 –Antenna Specifications

The MPE distance in Table 4 is the uncontrolled maximum distance for each antenna. For the data collection and meter transmission units, 20 cm (8 inches) is the recommended distance regardless of whether or not a closer distance is still within compliance. A known duty cycle of 15% was taken into account when finding the MPE distance for the Elster Gatekeeper.

Since the Tropos mesh router device uses two different antennas, a cumulative exposure limit must be defined for the appropriate MPE distance of the entire unit.

Device Specifications

Model	Transmitter Power Range	
	dB_m	Watts
Tropos 6320 2.4 GHz	20 - 35	0.1 – 3.16
Tropos 6320 5.8 GHz	19 - 34	0.079 – 2.51
Tropos 7320 2.4 GHz, 5.8 GHz	21 - 36	0.126 – 3.98

Table 5 –Device Specifications

Cumulative Exposure Limit

For devices with more than one antenna transmitting at different frequencies, the allowed cumulative exposure at a given distance from the radiating device (the sum of the ratios of power density at the given distance to the maximum power density) must be less than 1 (IEEE Std. C95.1-2005 Section D.2). If the period signal is known, the cumulative exposure is multiplied by the duty factor.

	CONTROLLED		UNCONTROLLED	
Module	**Power Density @ 10.22 cm (4 in)**	**% Max Power Density**	**Power Density @ 23 cm (9.1 in)**	**% Max Power Density**
2.4 GHz	2.897 mW/cm^2	57.9%	0.572 mW/cm^2	57.2%
5.8 GHz	2.098 mW/cm^2	42.0%	0.414 mW/cm^2	41.4%
Cumulative Exposure:	**99.9% Maximum Exposure**		**98.62% Maximum Exposure**	

Table 6 – Cumulative Exposure for Tropos Routers

At 4 inches, the Tropos router is at 99.9% of its controlled MPE limit and at 9.1 inches, it is at 98.62% of its uncontrolled MPE limit. In other words, if you are at least 9.1 inches away from the router, you are within the MPE limit.

Compliance Boundary

For the Tropos mesh router units, as defined in Table 6, the minimum distance a qualified worker can stand next to the antenna is 10.22 cm (~ 4 inches). This is based on the averaging time of 6 minutes and under the pretense that the worker is under the controlled category. Compliance boundaries for both controlled and uncontrolled will be visibly indicated near the unit. The following table lists compliance boundaries for each transmitting device deployed in SVP territory based on continuous maximum antenna power output.

Note: Since it is possible for the associated radio to operate at a smaller power than the antenna's maximum capabilities or that transmission is periodic, Table 7 defines the *worst case* conditions for the antenna. If the radio maximum power output and/or duty cycle is known, it may be possible to obtain a smaller compliance boundary.

The uncontrolled and controlled limits for 900MHz are 0.6mW/cm^2 and 3.0mW/cm^2, respectively. Since the duty cycle of the Elster Gatekeeper is known to be 15%, using **Calc. 1**, our new power density limits are

Controlled: 0.6 / 0.15 = 4 mW/cm^2
Uncontrolled: 3.0 / 0.15 = 20 mW/cm^2

These limit values are used to find the compliance boundaries for the gatekeeper via **Calc. 3**.

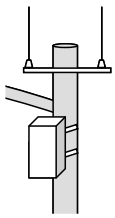
Device	Owner	Maximum Antenna Gain	Controlled Compliance Boundary	Uncontrolled Compliance Boundary
 Tropos 7320	SVP	8 dB_i	4 inches	9.1 inches
 Elster Gatekeeper	SVP	5.64 dB_i	0.75 inches	1.69 inches
 SkyPilot Connector	SVP	16.30 dB_i	10.28 inches	22.95 inches
 SkyPilot Extender	SVP	18 dB_i	12.48 inches	27.91 inches
 Meter Transmission Unit	PG&E	0 dB_i	8 inches	8 inches
 Data Collection Unit	PG&E	-	8 inches	8 inches

Table 7 – Compliance Boundaries

Rev.	Date	Description	Appr.	Rev.	Date	Description	Appr.

By: A. Saenz	RF Unit Clearances	Drawn By: L. Mangoba	
Approved: October 6, 2011		SHEET 12 of 17	
Albert Saenz		SD 1275	Rev. 0
Orville Plum	Silicon Valley Power		

The Tropos 7320 devices consist of 4 omni-directional antennas. For qualified workers, a distance of 4 inches is to be kept from each antenna in all directions while the general public must keep a distance of 9.1 inches as illustrated in Figure 4.

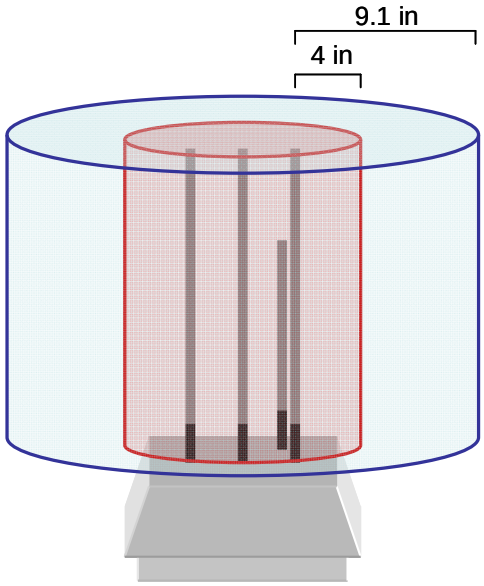


Figure 4 – Compliance Boundary

Compliance with Pole Clearances

Climbing Space

Mounted antennas should not be placed such that the compliance boundaries are within the pole's climbing space, as required by General Order (GO) 95 Rule 54.7. The vertical climbing space, maintained from the ground level, have defined square dimensions given in Table 8 that are based on arm construction and the voltage of the conductor.

	DIMENSIONS OF SQUARE CLIMBING SPACE	
Voltage (L-G)	**Line Arms Only**	**Line and Buck Arms**
0-7500 V	30 in	30 in
7500-46000 V	36 in	42 in
> 46000 V	36 + (1/2 per kV in excess of 46 kV) in	-

Table 8 – Climbing Space Dimensions

Figure 5 illustrates a top view example of an appropriate antenna placement on a utility pole constructed with only line arms and an example of a wrong placement. The top image shows the compliance boundary region separated from the climbing space region. On the bottom image, the regions overlap and do not follow GO 95 Rule 54.7. Note: Units that are placed on arms of street lights must be positioned such that the compliance boundaries do not overlap with the cobra head. This is also illustrated in Figure 5.

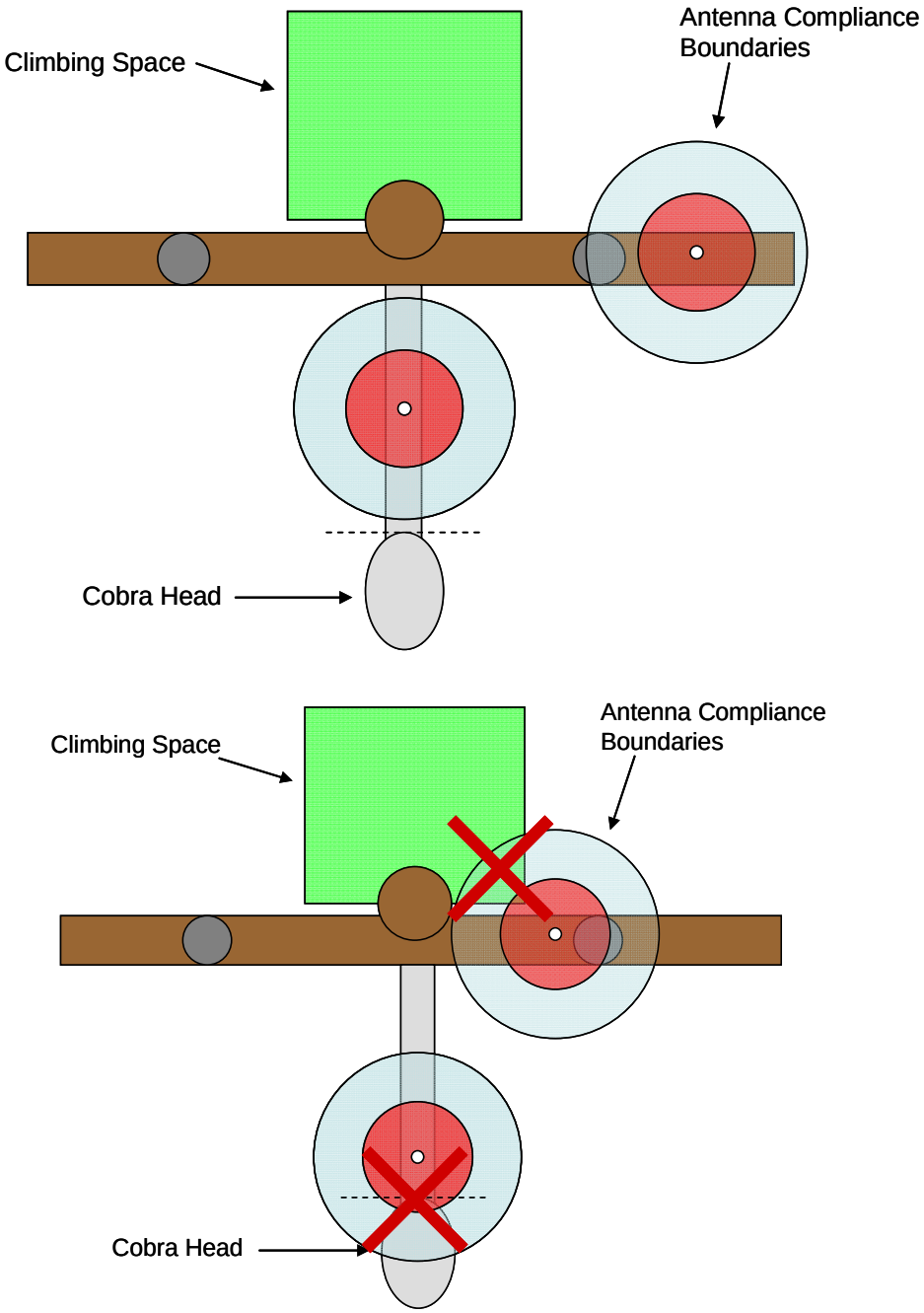


Figure 5 – Top View Pole Climbing Space and Cobra Head Clearances

Other Clearances

Along with climbing space, additional clearances are defined for the antenna structure (antennas, support elements, associated equipment) and other elements on the pole. Figure 6 illustrates the pole clearances for antennas at different placements (GO 95 Rule 38 Table 2).

Type of Clearance	Clearance Dimension
Supply Conductors and Trolley Feeders 0-750 V[1,2] (L-G) 750-35000 V (L-G) 35000-75000 V (L-G)	 Vertical: 4ft Vertical: 6 ft Vertical: 10 ft
Trolley Contact Conductors[1]	Vertical: 4 ft
Communication Conductors[3]	Vertical: 2 ft
Centerline of Pole[4]	Horizontal: 2 ft
Ground Line	Vertical: 8 ft

[1]Clearances for exposed associated cables may be reduced by 12 inches.

[2]Clearance from service drop point of attachment on structure to Antenna(s) and associated supporting elements may be reduced to 10 inches.

[3]May be reduced to 10 inches for cables installed by Antenna owner/operator.

[4]When antenna is affixed between supply and communication lines or below communication lines.

Note: SVP owned antennas can be treated as supply equipment, thus making the clearance requirement 2 ft.

Table 9 – Utility Pole Clearances

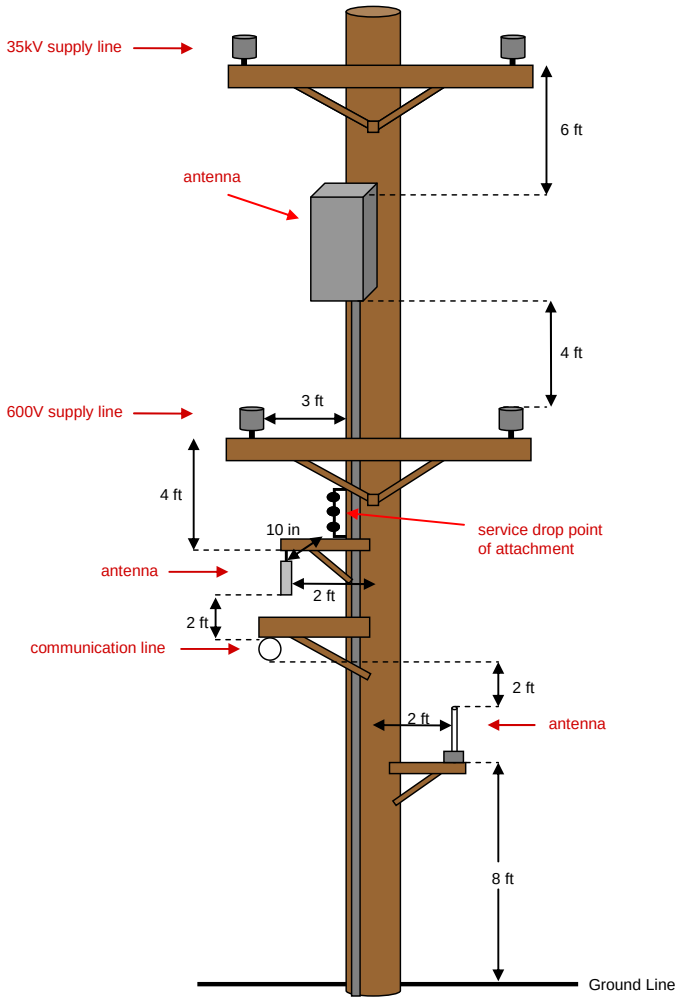


Figure 6 – Pole Clearances

Note: Not to scale. Clearance limits are for reference only. SVP does not allow antennas on power poles.

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Safety Procedure

Per OET Bulletin 56, maintenance personnel required to work near an antenna structure must take precautions as to prevent any harmful exposure. These precautions may include de-energizing the unit or maintaining the compliance distance.

Marking Requirements for Street Light Mounted Devices

All workers must review the RF safety document before performing work to a router-mounted streetlight. If the document is not given, the containing information should be requested. The non-ionizing radiation sign is displayed near each unit.

Figure 7 – Non-Ionizing Radiation Sign

In addition to the sign in Figure 7, all devices mounted on street lights will display a clearance label specifying both controlled and uncontrolled compliance boundaries. With the radiation sign and clearance label displayed by each device, workers are able to identify the transmitting antenna and keep the safe distance away from it.

Marking Requirements for Utility Pole Mounted Devices

For antennas mounted on utility poles, a weather and corrosion resistant sign indicating the compliance boundaries for both controlled and uncontrolled categories will be affixed on to the pole. The sign will also indicate the following:

- Identification of the antenna operator (control center)
- 24 hour contact number of antenna operator for Emergency or Information
- Unique identifier of the antenna installation
- Frequency(s) of radiating antenna(s)

The sign will be placed at least 3 feet below the antenna (from the top of the sign) and at least 9 feet above the ground (from the bottom of the sign).

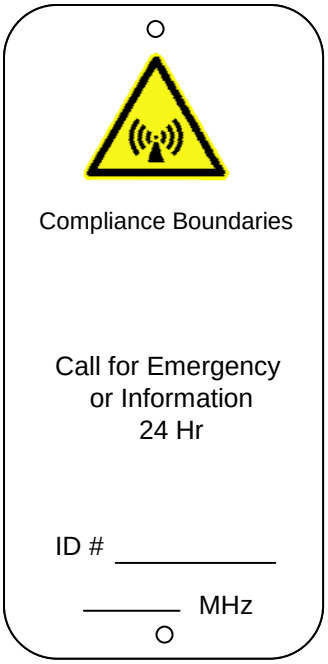

Figure 8 – Caution Sign

System Shutoff and Removal

In the event that work on a utility pole or street light is needed within the compliance boundary (i.e. maintenance/repairs), the worker must first de-energize the unit by doing the following:

1. Identify the unique ID tag posted on the pole or on the device.
2. Find the control center call back number to provide site location and request to de-energize the unit. (Contact number should also be displayed on the sign) The operator will provide further instructions on how the unit will be de-energized.
3. Verify unit is de-energized (means to verify system shutoff should be explained by called operator) and proceed with work.
4. After completion, contact control center and inform them that the unit can be re-energized. Units will not be re-energized without confirmation of completed work by worker. If prior written consent is given, workers can re-energize the unit themselves.

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In cases of emergency working conditions in direct response to unanticipated events, or if it is necessary for the device to be removed completely, the utility worker should make a good faith effort to follow the previous steps 1-4 and refer to the corresponding Standard Operational Procedure document for further instruction and alternative procedures.