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An Evaluation of Potential Radiofrequency Field Exposure Levels Associated with the Sky Valley Telecommunications Monopole

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Summary

The Snohomish County Public Utility District (SNOPUD) #1 is planning the installation of a new 120 foot tall telecommunications monopole at the Sky Valley substation located in Monroe, WA. The monopole will support six antennas to provide for radio communications within the SNOPUD consisting of one (1) receive only antenna located at the top of the structure and five (5) other antennas at lower levels that will provide both receive and transmit capability. This report addresses the radiofrequency (RF) electromagnetic fields produced by the transmitting antennas that could result in exposure of individuals in the vicnity of the monopole. The purpose of the evaluation was to assess whether any active transmitting antennas on the new monopole might result in noncompliance with limits on human exposure established by the Federal Communications Commission (FCC)[1] and requirements of the Washington Department of Labor and Industries (L&I)[2].

The evaluation process consisted of theoretical analysis of the magnitude of RF fields at ground level within 500 meters (m) (1640 ft) of the monopole as well as RF fields that might result in exposure of personnel performing maintenance of antennas on the monopole at various heights above ground. The analysis at ground level included the effect of the directional transmitting properties of the different antennas within the elevation plane following guidance by the FCC including the application of a recommended ground reflection factor, the output powers of the various transmitters, the antenna heights above ground and the frequency of the transmissions. The on-monopole analysis involved a near-field approach to estimating the spatially averaged RF field power densities close to the antennas to which a worker might be exposed when working aloft. Both approaches, used for ground level RF fields and the on-monopole fields, were conservative and were designed to result in potential over-estimation of RF field exposure.

The ground level analysis found that the maximum RF field exposure of persons anywhere on the ground in the vicinity of the monopole, assuming that all transmitters were simultaneously transmitting, could be as great as 2.2% of the FCC maximum permissible exposure (MPE) for members of the general population. In reality, actual exposure levels are expected to be substantially less than this value because of the intermittent transmit activity of the five transmitters and the fact that the calculated RF field level was intended to represent a spatial peak value as opposed to the spatially averaged value, which would be lower, specified by the FCC rules.

[1] 47 CFR § 1.1310. Radiofrequency radiation exposure limits.

[2] Requirements of the Washington State Department of Labor and Industry relative to RF exposure are found in the Washington Administrative Code Chapter 296-32. In WAC 296-32-22575, application of the FCC MPEs is specified.

RF fields calculated for personnel approaching the various transmitting antennas when working aloft were determined for conditions of workers ranging from 1 to 4 feet from any of the antennas (equivalent to a worker being between 2 and 5 feet from the surface of the monopole due to the 6 ft standoff mounting distance of each antenna relative to the monopole). The only condition in which maximum potential exposure to RF fields would be expected to exceed worker limits was found to be associated with operation of the single VHF antenna at the 72 foot height on the monopole (this is principally because of the lower operating frequency at which the MPE is most restrictive). The analysis showed that if workers remain at least 3 feet from this one antenna, potential exposure will comply with the FCC occupational MPE as well as the Washington Department of L&I. Exposure near the other antennas was not determined to exceed the MPE for workers, regardless of proximity.

In summary, operation of the proposed telecommunications monopole will comply with the FCC rules on human exposure for persons on the ground by a wide margin. Personnel accessing active antennas at various heights on the monopole will need to honor a distance of 3 feet from the one VHF antennas, when it is active, in order to comply with the FCC MPE and Washington Department of L&I for occupational exposure. Should closer access be required, the antenna should be put out of service during the time that immediate access is required. The SNOPUD should implement an RF safety program that provides for the RF awareness education and RF safety training required by the Washington Department of L&I to help ensure that RF exposure of employees and subcontractors is compliant with the FCC MPEs at all times. Guidance on development of RF safety programs can be found in IEEE C95.7-2014[3].

This evaluation shows that the proposed telecommuncations monopole will comply with requirements for controlling exposure of the public by a wide margin. Compliance for exposure of workers when working aloft requires respecting the necessary clearance distance from the one VHF antenna at the 72 ft height. RF safety signage should be posted at the base of the monopole to remind workers who may be required to access the antennas that active antennas are present near the top of the pole. Only SNOPUD personnel, or subcontractors, who have been provided with appropriate RF safety information and are using a personal RF monitor should access the monopole. These recommended procedures for workers should be a part of the SNOPUD RF safety program.

Introduction

Exposure to very intense RF fields can result in high rates of energy deposition in the body, leading to an increase of local tissue temperature and the core body temperature as a whole. To protect against any potential adverse health effects, exposure lmits for RF fields associated with transmit antennas have been promulagated by the FCC in the form of maximum permissible

[3] IEEE Std C95.7-2014 Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz. Available at https://ieeexplore.ieee.org/document/6874474.

exposures (MPEs). The MPEs specify two different sets of exposure limits for RF power density, one set that is applicable to members of the general population and another set applicable to persons that are occupationally exposed with the general population limits being five fold lower than those for occupational exposure. The MPEs depend on frequency since the body absorbs RF energy based on the physical size of the person. Further, the MPE values represent the magnitude of power density that is averaged over the dimensions of the body (typically the height of the person) and over time. For public exposure, the averaging time is any 30-minute period; for occupational exposure, the averaging time is 6 minutes. The FCC MPEs are shown in Appendix A. The MPEs specified in Appendix A are recognized as applicable to the Washington State Department of Labor and Industries.

This report documents an evaluation of RF fields that could be associated with operation of a new telecommunications monopole at the Sky Valley substation in Monroe, WA for purposes of assessing potential exposure of the public in the vicinity of the monopole as well as workers who may access the antennas at elevated locations above ground.

Proposed Transmitting Equipment

A total of six antennas are proposed for installation on the Sky Valley monopole; five of these will support transmission of radio signals with one being used for receive purposes only. These antennas are tabulated in Table 1 showing their specifications and location on the monopole.

Table 1. Antennas proposed for installation on the Sky Valley monopole.[a]

Antenna ID	Frequency (MHz)	Model	Length (ft)	Mounting height (ft)	Input Power (W)	Gain (dBi)
Rx 1	NA	Sinclair SC-499	11.7	112	100	11.15
Tx 1	937-939	Sinclair SC-499	11.7	97	100	11.15
Tx 2	937-939	Sinclair SC-499	11.7	97	100	11.15
TxRx	940-941	Sinclair SC-499	11.7	82	100	11.15
TxRx	940-941	Sinclair SC-499	11.7	82	100	11.15
TxRx	152-153	RFS BA1010-1	4.7	72	100	2.15

[a] All antennas are specified to be mounted with a standoff of six feet from the monopole.

Technical Approach to Evaluation

RF fields were evaluated using a theoretical modeling approach for both (a) the ground level fields and (b) fields very close to the antennas on the monopole. For ground level fields, the elevation plane patterns of the antennas were employed with a specified maximum power of 100 watts (W) and main beam gain specification to calculate the RF field near the ground. An FCC recommended ground reflection factor of 2.56 was applied to obtain an estimate of the maximum likely field power density[4]. Calculated ground level fields are the maximum (spatial peak) value to which a person standing on the ground could be exposed and are expressed as a percentage of the FCC MPE for general population exposure as a function of distance from the monopole.

RF fields near the monopole mounted antennas were calculated using a software tool (RoofView® version 5[5]) to obtain estimates of the spatially averaged power density in the near field region of the antenas. The spatially averaged power densities over the dimensions of a six-foot tall worker are expressed as a percentage of the FCC MPE for occupational exposure. Plots of RoofView® calculated fields illustrate the potential exposure levels in a horizontal plane as if looking down on the monopole. The results were also rearranged to illustrate the fields at different heights on the monopole in a side view style.

Results

Ground level RF field analysis

Figures 1 and 2 illustrate calculated ground level RF fields adjacent to the monopole with the assumption that all transmitting antennas are simultaneously active. Figure 1 is a logarithmic plot on the distance scale and reveals that the maximum RF field anywhere on the ground is 2.24 % of the FCC MPE for public exposure at a distance of 16 meters (m) (52.5 feet) from the base of the monopole. These same data are displayed on a linear plot on the distance scale in Figure 2. The pronounced peak at 16 m from the monopole is due to the elevation plane pattern of the various antennas. The 900 MHz band antennas with narrower elevation plane transmit patterns demonstrate a narrower peak while the much lower gain VHF antenna has a much broader patttern of maximum ground level field. Nonetheless, the ambient composite field level is a small fraction of the MPE.

RF field analysis at heights on the monopole

The analysis results for close exposure to the antennas on the monopole are shown in Figures 3 through 6. A top down view of calculated RF fields at the 72 foot level of the monopole (the mounting height of the single VHF antenna) illustrates the spatial distribution of fields as a percentage of the FCC MPE for occupational exposure. Generally, the analysis shows that at the height of the VHF antenna, exposure of personnel will clearly exceed the public MPE and if the

[4] See FCC OET Bulletin 65, Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, Edition 97-01. August 1997.

[5] RoofView® is a product of Richard Tell Associates, Inc.

worker is relatively close to the active antenna, the occupational MPE could also be exceeded, typically within two feet of the antenna. The maximum expected potential exposure at this height is 287.7% of the FCC occupational MPE.

Figure 4 presents the spatial distribution of RF fields at the 82 foot level, the mounting height of two of the UHF antennas. At this height the maximum potential exposure represents 62.1% of the FCC occupational MPE.

Figure 5 illustrates the spatial distribution about the monopole at the 97 foot level, the mounting height of the top two transmitting antennas. At this level, the maximum potential exposure reprsents 55.2% of the FCC occupational MPE.

Finally, in Figure 6, potential RF exposure for personnel is presented for different distances from the surface of the monopole vs. height on the monopole. While Figures 3 – 5 show how the RF field is distributed at the point of maximum potential exposure at the three different antenna mounting height, Figure 6 shows the potential exposure all along the axis of the monopole. Figure 6 reinforces the finding that RF fields above 75 feet on the monopole do not exceed the occupational MPE; they can, however, exceed the general population MPE.

Discussion

The analyses of RF fields that might be expected in the vicinity of the Sky Valley monopole show that potential ground level exposure of individuals will be a small fraction of the more stringent FCC MPE for general population exposure with a maximum expected value of 2.24% of the MPE. This theoretical value is conservative since the calculation included a ground reflection factor that increases the power density of the incident RF field by a factor of 2.56 times to account for the possibility of ground reflected fields that would enhance the field strength at a point in space near ground level. Since the FCC MPEs are in terms of sptially averaged power densities, however, actual exposures at ground level would be expected to be less than the calculated values. The results also illustrate how the transmitting patterns of the antennas affect the ground level values; because of side lobes of emitted signals below the horizon, there exists a point lateral to the base of the monopole where the ground level signal strength will be greatest (corresponding to 2.24% of the MPE), this occurring at 16 m (approximately 52.5 feet) from the base of the monopole.

The analyses of potential exposure of workers aloft on the monopole show that the greatest RF fields will exist adjacent to the lower mounted VHF transmitting antenna at 72 feet above ground. The reason for this finding is two fold: (a) the smaller size of the antenna which means that the transmitted power (which is the same as all of the other transmitting antennas) is concentrated within a shorter transmitting aperture, increasing the power density close to the antenna and (b) the lower frequency in the VHF band which corresponds to the frequency range within which the FCC MPEs are the most stringent because of enhanced body absorption of the RF energy from the fields. This can be seen by referring to the MPE values in the Appendix, showing that the MPE is at the lowest value in the frequency range of 30 MHz to 300 MHz (the body resonance range).

Nonetheless, the FCC occupational MPE is only expected to be exceeded within a distance of 2 feet of the VHF antenna. Since the antenna will be mounted 6 feet away from the monopole, any region within 4 feet of the monopole will remain compliant with the occupational MPE for trained workers. Exposures will exceed the general population MPEs meaning that those who access regions above 60 feet on the monopole will need to be provided with RF safety awareness education and RF safety training to avoid exceeding the occupational MPE.

Because the other transmitting antennas on the monopole operate at significantly higher frequencies in the 940 MHz range (where the MPE is less restrictive) and have longer transmitting apertures (physical length of the antenna), exposure of workers aloft are not expected to exceed the occupational MPE. However, since exposure would be expected to exceed the general population MPE, they must be provided with the same RF safety awareness education mentioned above. The RF safety awareness education provides the necessary information to the worker to make them subject to the more lenient occupational MPE.

The focus of this analysis of potential RF exposure is related to compliance with the applicable exposure limits contained in both federal and Washington State rules. These rules are based on controlling exposure of the human body to prevent potentially adverse health effects associated with excessive energy absorption rates within the body that could lead to elevated temperatures in the body tissues. At the same time, it should be pointed out that strong RF fields also have the potential for interference with certain implanted medical devices such as cardiac pacemakers and defibrillators. While environmental limits on RF fields to prevent such interference do not exist, manufacturers do conform to international standards that recommend minimum interference immunity levels for the products that they make.

Conclusions

The subject Sky Valley monopole does not represent a significant RF safety concern because the very maximum potential exposures are no more than approximately 2.9 times the occupational limit with immediate proximity to the VHF antenna. While controlling occupational exposure is a regulatory issue and must be complied with, this maximum possible exposure is substantially less than the exposure presumed to represent the threshold for adverse effects which is ten times the occupational MPE.

Further, the elevated exposure that might occur to a worker near the antennas can be mitigated by controlling the exposure time. In the case of the VHF antenna, even the maximum projected RF field near the surface of the antenna of 2.9 times the MPE means that based on the 6-minute averaging time of the FCC MPE for occupational exposure, an exposure of 2.07 minutes during any 6-minute period would comply with the MPE as long as there is no additional exposure during the remaining nearly 4 minutes of the 6-minute averaging time. Hence, during typical access of the monopole for routine maintenance activities, as an example, time averaging could be a significant migitaging factor for remaining compliant with the MPE. Indeed, however, if extended time is required in close proximity of any of the transmitting antennas, the associated transmitter(s) should be shut down during the work and normal lockout/tagout procedures followed.

An appropriate RF safety alerting sign should be affixed to the monopole near its base to remind workers who may require elevated access on the monopole that caution is required when working near the active antennas, that they must have been provided with RF safety information prior to working aloft and should be using a personal RF monitor.

SNOPUD employees as well as subcontractor personnel who may need to work in the near vicinity of any antennas on the monopole should be subject to a SNOPUD RF safety program and must have received, at a minimum, RF safety information that:

- Explains what RF exposure is
- Explains the existence of regulatory exposure limits and the difference between occupational and general public exposure limits
- Informs workers who may be reliant on implanted medical devices about potential RF interference
- Provides insight on areas of potentially elevated RF exposure on the monopole
- Gives guidance on remaining compliant with exposure limits when working near antennas
- Explains the use of a personal RF monitor
- Gives lockout/tagout work procedures when work will require physical access to antennas.

The analysis demonstrates that operation of the Sky Valley monopole will comply with the FCC regulations by a significant margin for the public for any point on the ground. Further, if relevant exposure distances are controlled for workers accessing monopole installed antennas, along with appropriate RF safety education/training and the use of personal RF monitors for workers as a part of an RF safety program, the FCC and Washington WAC rules for those occupationally exposed will also comply with the required exposure limits.

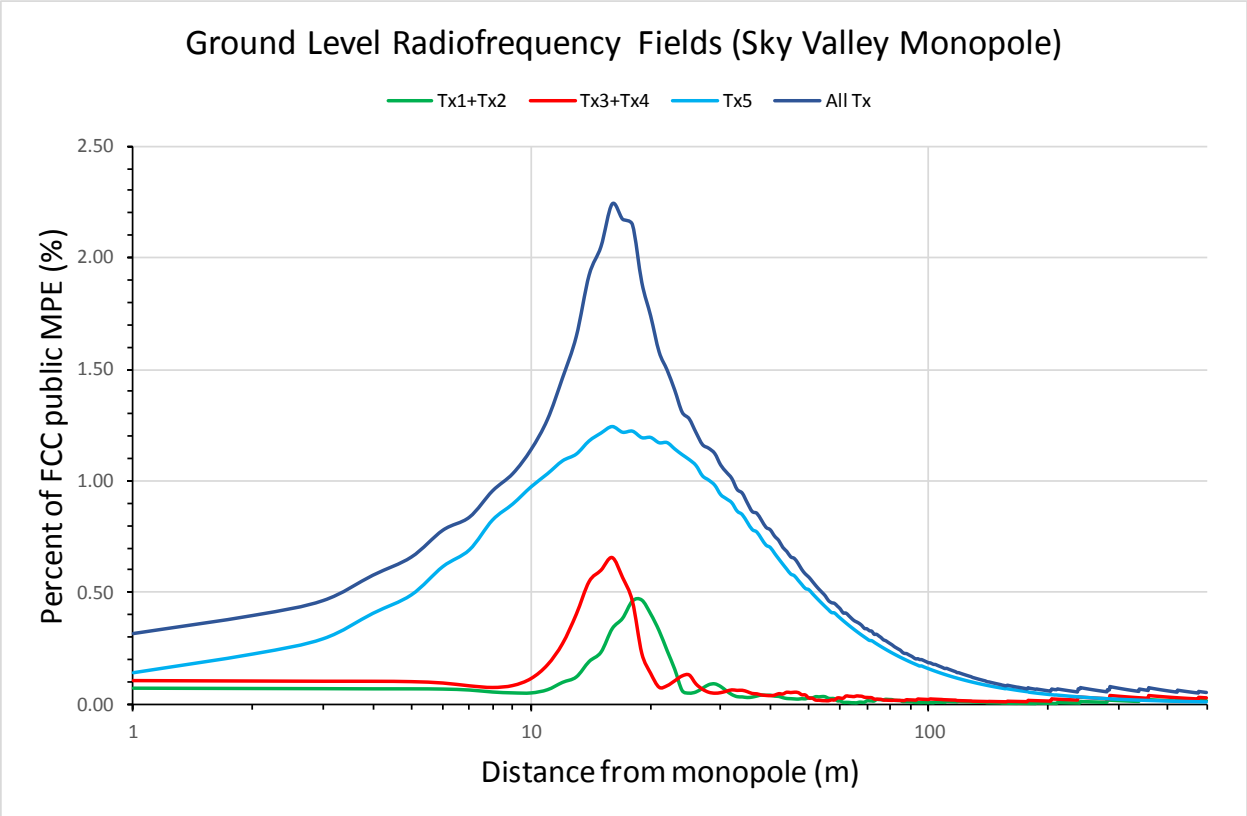

Figure 1. Logarithmic display of ground level RF fields adjacent to the Sky Valley monopole showing the contribution of the fields from different antennas as a percentage of the FCC MPE for public exposure.

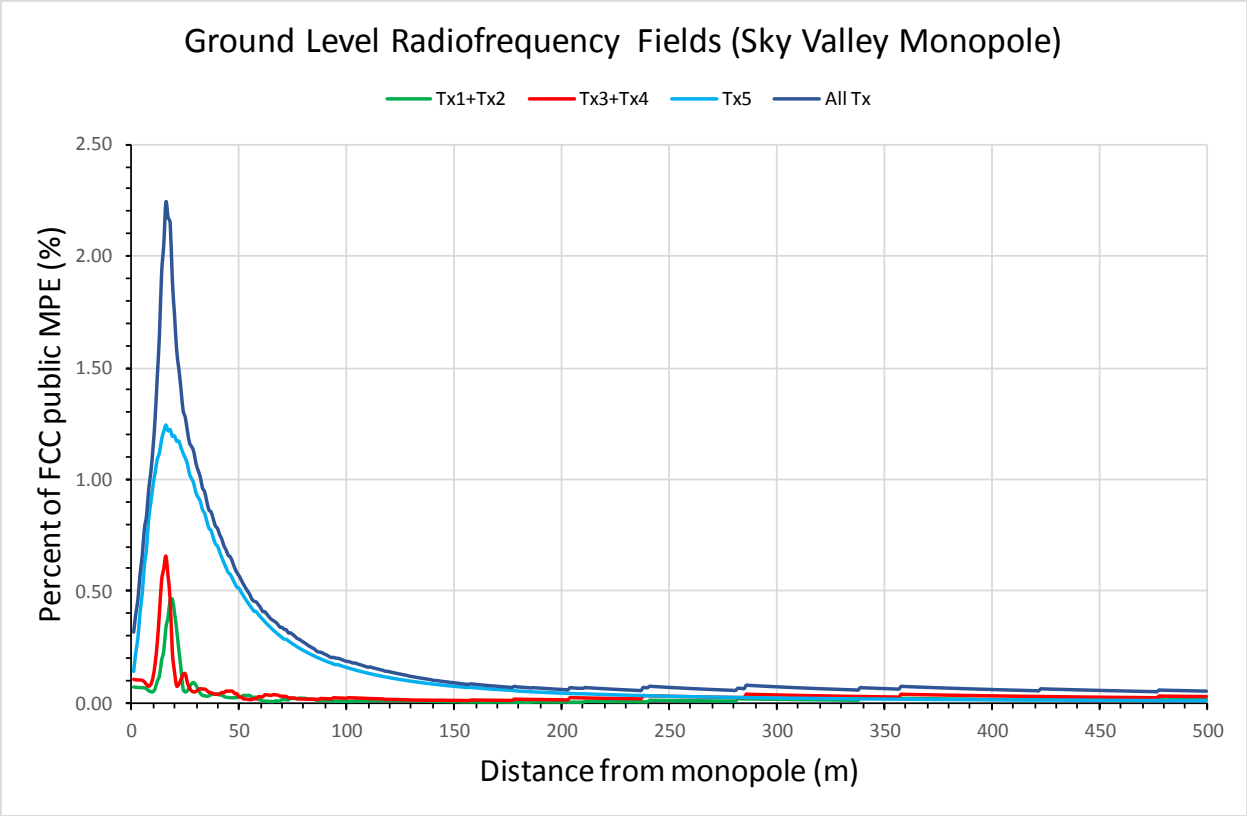

Figure 2. Linear display of ground level RF fields adjacent to the Sky Valley monopole showing the contribution of the fields from different antennas as a percentage of the FCC MPE for public exposure.

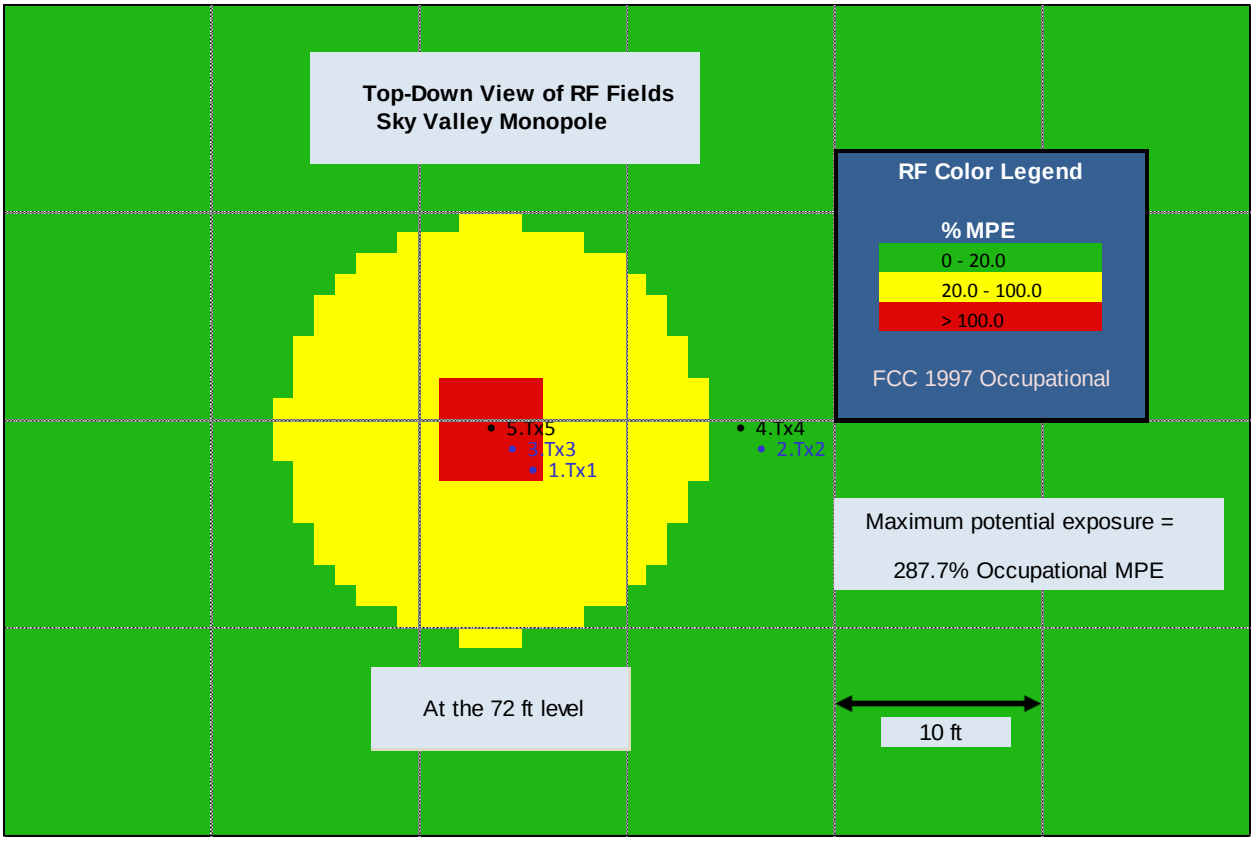

Figure 3. Top down view of the spatial distribution of RF fields at the 72 foot level on the Sky Valley monopole. Colors represent ranges of potential exposure near the antennas in terms of the FCC occupational MPE.

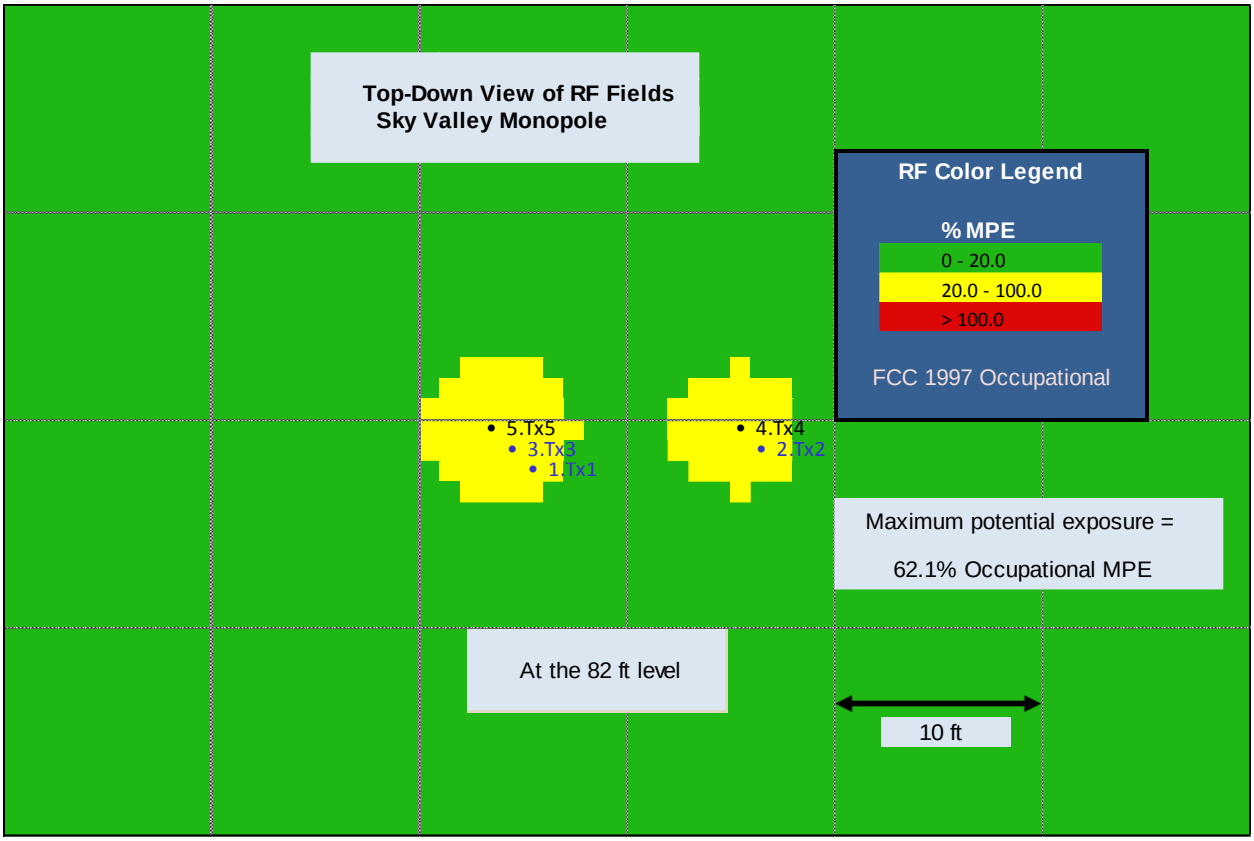

Figure 4. Top down view of the spatial distribution of RF fields at the 82 foot level on the Sky Valley monopole. Colors represent ranges of potential exposure near the antennas in terms of the FCC occupational MPE.

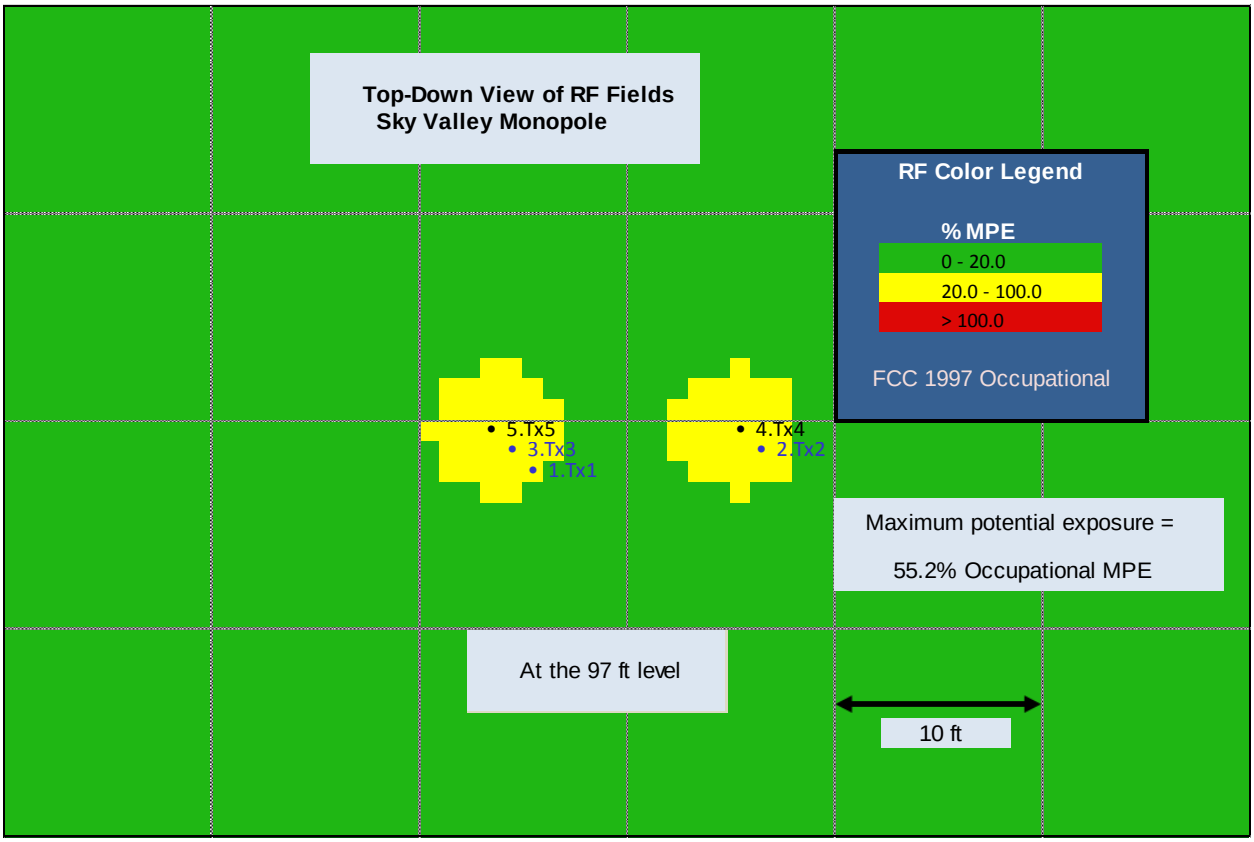

Figure 5. Top down view of the spatial distribution of RF fields at the 97 foot level on the Sky Valley monopole. Colors represent ranges of potential exposure near the antennas in terms of the FCC occupational MPE.

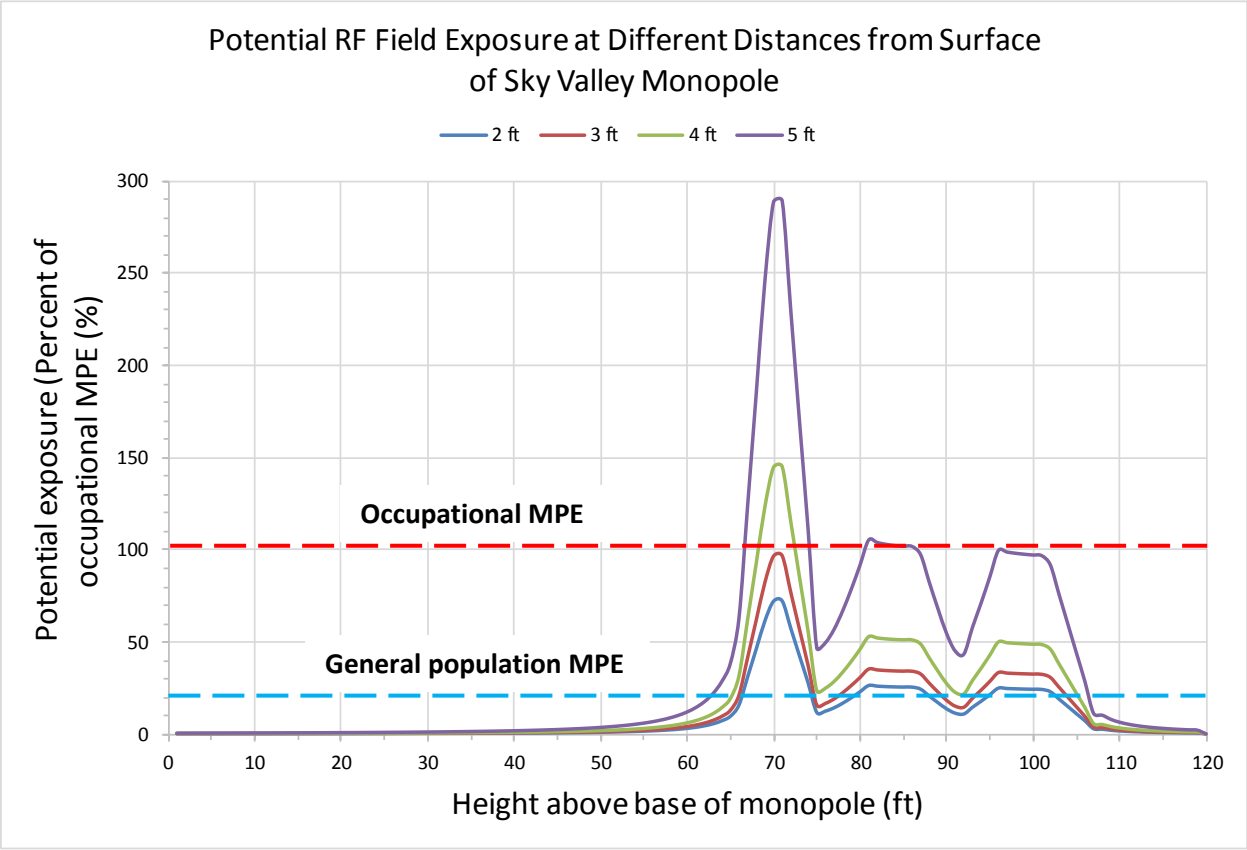

Figure 6. Potential RF field exposure at different lateral distances from the surface of the Sky Valley monopole as a function of height on the monopole. When at no more than 3 feet from the monopole, the public MPE may be exceeded in the height range 67-76 ft above base of monopole. At distances exceeding 3 feet from the monopole, higher fields exist due to proximity to the antennas and the occupational MPE can be exceeded near the VHF antenna at 72 feet above ground.

Appendix
FCC Maximum Permissible Exposure Values

Maximum Permissible Exposure (MPE) values have been reproduced from the FCC OET Bulletin 65.

Table 1. LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

(A) Limits for Occupational/Controlled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $|E|^2$, $|H|^2$ or S (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	($900/f^2$)*	6
30-300	61.4	0.163	1.0	6
300-1500	--	--	f/300	6
1500-100,000	--	--	5	6

(B) Limits for General Population/Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $|E|^2$, $|H|^2$ or S (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	($180/f^2$)*	30
30-300	27.5	0.073	0.2	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

f = frequency in MHz *Plane-wave equivalent power density

NOTE 1: ***Occupational/controlled*** limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.

NOTE 2: ***General population/uncontrolled*** exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure.

The relationship between MPEs expressed in terms of electric (E) or magnetic (H) field strength and power density (S) is given by the relationship below:

$$S(mW/cm^2) = \frac{E(V/m)^2}{3770} = H(A/m)^2 \times 37.7$$

If the unit for power density is W/m^2, the relationship is:

$$S(W/m^2) = \frac{E(V/m)^2}{377} = H(A/m)^2 \times 377$$

The values shown in the power density column of FCC's Table 2 are more accurately designated as plane wave equivalent power density. Below 300 MHz, it is conventional to express RF fields in terms of the E or H field strengths rather than power density (note that above 300 MHz, only power density values are given for the MPEs). In the far field of a source antenna, the ratio of the E field strength to the H field strength is 377 ohms, the so-called impedance of free space. This is the region in which a propagating wave would normally be referred to as a plane wave, i.e., no curvature across the front of the wave. In near-field environments, commonly taken to be distances less than $\lambda/2\pi$ from the source antenna, the electric and magnetic fields may not exhibit the same relationship as they do in the far field. The concept of plane wave equivalent power density is based on the assumption that the electric field and magnetic field strength components of the electromagnetic wave, regardless of distance from the source, are those values that would exist in a plane propagating wave of the given power density.