PINNACLE TELECOM GROUP
Professional and Technical Services

ASSESSMENT of WIRELESS ANTENNA SITE FCC RF COMPLIANCE

prepared for

VERIZON WIRELESS

"3RD & 72ND" SITE

[redacted]

May 27, 2014

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FCC Compliance Analysis Summary

At the request of Verizon Wireless, Pinnacle Telecom Group (PTG) has performed an independent expert assessment of radiofrequency (RF) emission levels and compliance with related Federal Communications Commission (FCC) regulations for a wireless base station antenna operation on a building at [redacted]

Verizon Wireless refers to the site by the name "3rd & 72nd", and its operation involves directional panel antennas arranged for sectorized service coverage and operating in the 700, 850, 1900 and 2100 MHz frequency bands.

This report addresses potential concerns that may exist involving the site landlord or other interested parties regarding the level of RF emissions caused by the Verizon Wireless antennas in key areas of interest – and whether the federally set limits for safe, continuous human exposure to RF emissions are satisfied in those areas. In other words, "Is it safe?" The answer is yes, and here we will explain why.

The federal government has established standards for safe, continuous human exposure to RF energy emitted by antennas, and those limits (called "Maximum Permissible Exposure", or MPE, limits) are embodied in the FCC rules and regulations. The FCC requires that all wireless antenna operators ensure compliance with the applicable MPE limits – one set for "uncontrolled" exposure of the general public (also referred to as the "general population"), and another for "controlled" exposure such as might occur in restricted-access areas such as building rooftops. (The latter limit is alternatively called the "occupational" MPE limit.)

In this case, we will conservatively apply the MPE limit for the general public to the analysis in all areas of interest.

Note that both the FCC and the Food and Drug Administration (FDA) have certified that *continuous* human exposure at RF levels up to and including the FCC MPE limit is considered to present no RF health risk. Moreover, the FCC MPE limit has been designed to provide appropriate protection for humans of either sex, all ages, all sizes, and under all conditions.

The FCC has published a series of standardized mathematical models for calculating the levels of RF emissions caused by wireless transmitting antennas. The models are designed to be conservative and overstate the calculation results relative to RF levels that actually occur from antennas; in that way, conclusions about RF safety can be made with great confidence.

In order to minimize potentially confusing technical jargon, the results of FCC compliance assessments are best described by expressing the calculated levels of RF energy as a simple percentage of the applicable FCC MPE limit – where the figure 100 percent serves as an easy-to-follow reference for compliance. RF levels (described in such percentage form) is lower than 100 percent indicate compliance with the FCC limit, while results above 100 percent indicate the limit is exceeded and there may be a need to mitigate the potential exposure.

The areas of FCC compliance interest are as follows: (1) at street level around the building; (2) on the roof; and (3) inside the building, directly below the antennas. Thee compliance calculations in each area of interest involve application of the Verizon Wireless operating parameters to standardized FCC formulas.

The conservatively-calculated results and compliance conclusions in the different areas of interest in this case are as follows:

- ***At Street Level:*** The maximum calculated RF effect at street level from the proposed antenna operation is 0.3680 percent of the FCC MPE limit for safe, continuous exposure of the general public.
- ***On the roof:*** Conservative calculations for the RF effect of the proposed antennas on the roof show an RF level of 95.25 percent of the FCC general population limit (which is equivalent to 19.05 percent of the FCC occupational MPE limit). Note that because this calculation omitted the power-attenuation effects associated with antenna line loss, actual RF levels on the roof will be significantly lower.
- ***Inside the Building under the Antennas:*** Conservative calculations show the maximum RF level inside the building, at the ceiling level and directly under any of the sectors, is 0.0713 percent of the same MPE limit.

Therefore, the conclusion we draw from this antenna site assessment is that the strictest RF safety-related requirements of the FCC are satisfied in all other areas of interest.

Because of the conservative methodology and operational assumptions applied in this compliance assessment, the RF levels actually caused by the antennas will be even less significant than the calculated results here indicate.

The results of this compliance assessment are not at all unexpected, for the following reasons:

1. The antennas operate with a very low transmitter power level, between 20 and 40 watts per channel, depending on the frequency band.
2. The type of antennas used by Verizon Wireless have strong directional (signal-focusing) characteristics in both the horizontal and vertical planes; almost all of the RF energy is directed toward the horizon (front of the antenna), and very little energy is emitted to the side, rear, or directly below the antennas. Even directly in front of the antenna, the RF energy is well contained within the subtended height of the antenna (so that when the antennas are mounted above head level, the RF exposure potential is low).

It may also be useful to put the calculated results in this case into an everyday layman perspective via comparisons to other common exposure situations. Consider the following:

- Measurements we have performed inside hundreds of residences (both private homes and apartments) across the country show the ambient RF energy levels to consistently be in the range of three to seven percent of the FCC limit, owing entirely to the RF energy emitted on an incidental

("leakage") basis by common household electric appliances and consumer electronics. These results are independent of any cellular antenna operations in the vicinity; the "before-and-after" measurements we have done show the same results.

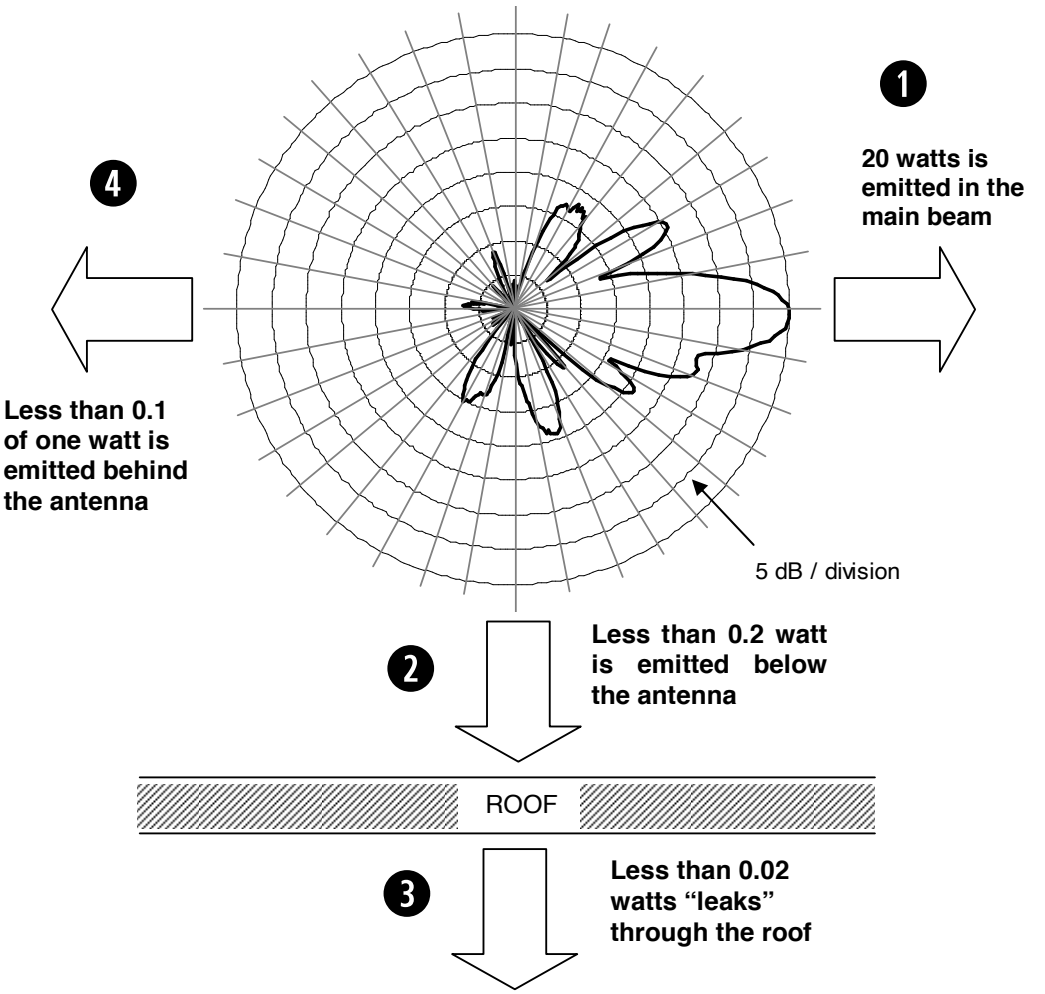
- Measurements have been performed by the US National Institute of Science and Technology (part of the Commerce Department) in the 50 largest US metropolitan cities. The results showed ambient street-level exposure averages 1.6 percent of the FCC limit – with *or without antennas in the immediate vicinity*, which is a clear indication that the primary sources of interest are the remote-but-high-power broadcast transmitters and the "RF leakage" from electronic and electric devices in the immediate vicinity. Similar PTG measurements in mid-size metropolitan areas indicate an average exposure of about one percent.

The diagram on the next page provides a graphic description of the antenna pattern characteristics and attenuation effects from the building structure that serve to keep the RF levels as low as they are in the various areas of interest.

The vertical-plane radiation pattern of a typical 1900 MHz directional panel antenna is shown, with the antenna effectively pointed toward the right. (See later pattern diagrams provided with the technical data for Verizon's operation.)

For ease of discussion, the example assumes a transmitter power of 20 watts and no line loss – in effect, an antenna input power of 20 watts per channel. Actual line loss results in a lower power level delivered to the antennas.

(Please see the explanation provided below the diagram.)



❶ Virtually all the RF transmitter power, 20 watts per channel in this example, is concentrated in the main beam in front of the antenna, and at the same height as the antenna. ❷ Because of the focusing effect of the antenna, the relative RF emissions in the "down" direction (directly below the antenna) are at least 20 dB lower (100 times lower). ❸ The RF emissions lose an additional 90 percent of their energy because of the attenuation caused to the signal by the structure of the roof. ❹ The RF energy emitted toward the rear of the antenna is lower than the main beam by a factor referred to as the "front-to-back" ratio – in this case 25 dB, or more than 300 times lower.

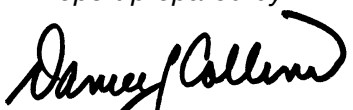
The antenna models used by Verizon Wireless exhibit even greater directivity than the one in the example. The minimum front-to-back ratio is 25 dB, and the "downward" discrimination is at least 30 dB.

In the immediate vicinity of the antenna (in what's called the "near field"), the RF levels are higher in front of the antenna and at the same subtended height, but are fairly low below, above, to the side, and to the rear of the antenna – and decrease with increasing distance from the antennas in any direction.

Complete descriptions of the underlying data and analyses are included in the first two appendices to this report. Appendix A provides the relevant technical data for the antenna operations, and Appendix B provides the necessary background, methodology and calculations for the FCC compliance analysis. In addition, Appendix C is included to provide a summary of the background and expert qualifications of the author of this compliance analysis.

One final note: We recognize there may be a question about the RF emissions from the radio equipment cabinets or the antenna cabling. While there are no mathematical models to perform calculations of such "RF leakage" levels, we have performed RF measurements at thousands of antenna sites, and besides measuring the RF effects of antennas, we have also performed measurements in the immediate vicinity of the RF equipment. In the immediate vicinity of the equipment cabinets the measured RF levels are consistently in the same range as the incidental "RF leakage" common to all electronic equipment – and the maximum is less than three percent of the FCC limit for safe, continuous exposure of the general public. In addition, the incidental "RF leakage" associated with the antenna cabling is consistently less than one-half of one percent of the FCC limit. Therefore, the "RF leakage" levels associated with the RF equipment and its associated cabling are insignificantly low and present no RF health risk for anyone in the vicinity.

Report prepared by

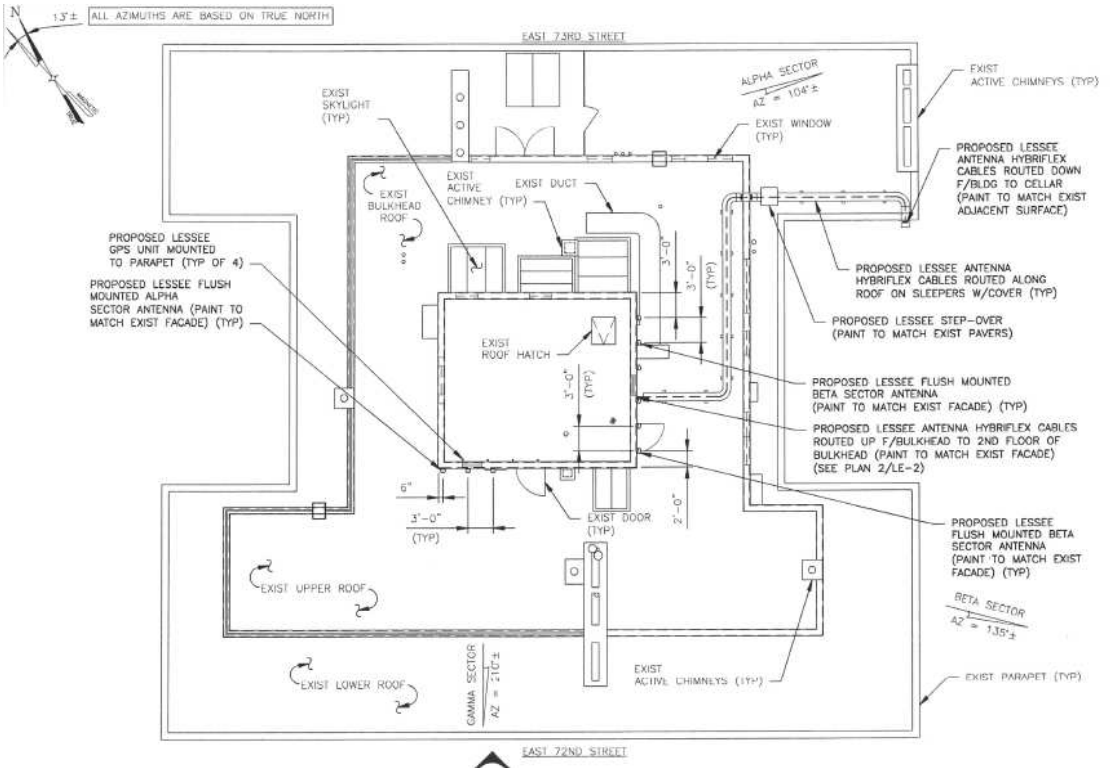


Daniel J. Collins, Chief Technical Officer
Pinnacle Telecom Group, LLC

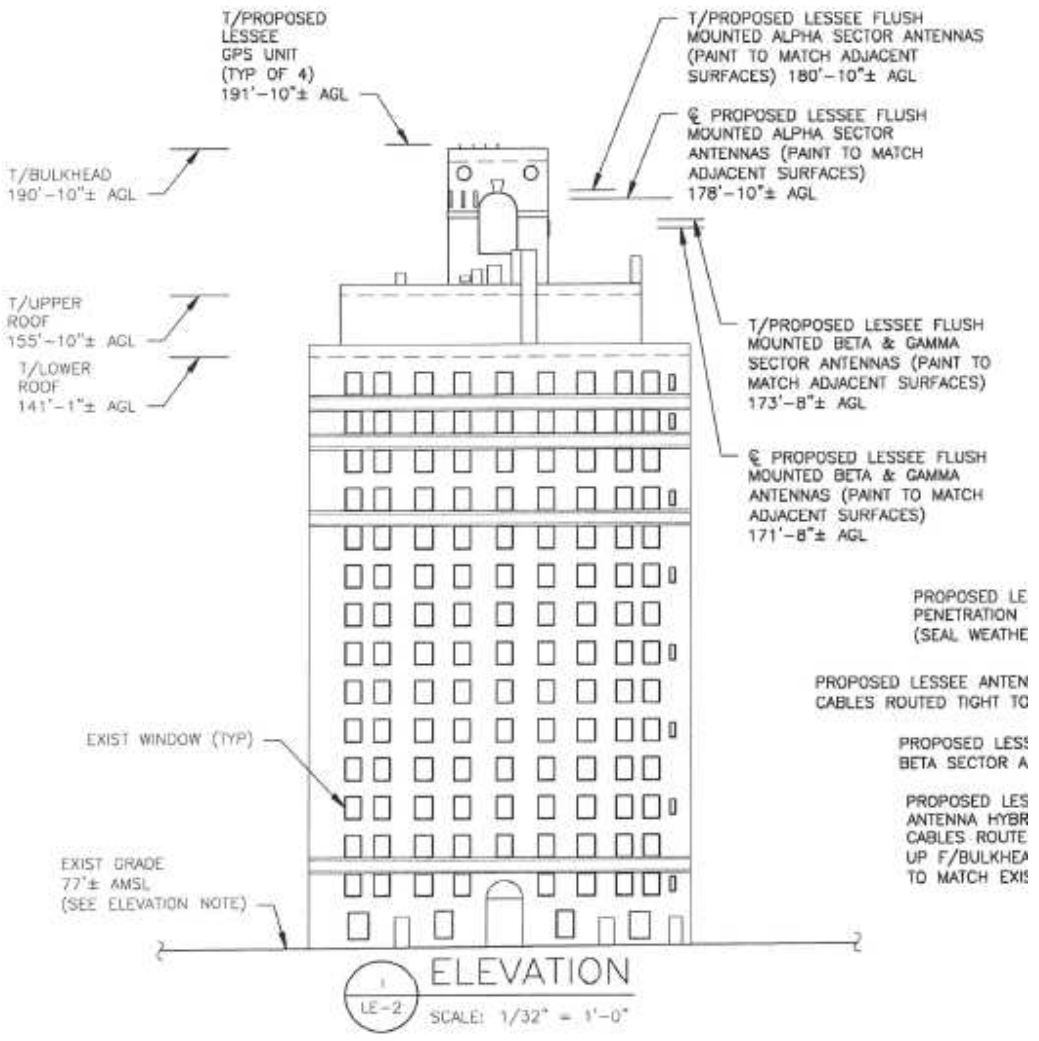
Appendix A. Verizon Antenna and Transmission Data

The diagrams below, extracted from the site drawings, illustrate the mounting positions of the Verizon Wireless antennas at the site.

Plan View:



Elevation View:



Verizon Wireless is licensed by the FCC to operate in the 700, 850, 1900 and 2100 MHz frequency bands. In order to be as conservative as possible, we will assume in the analysis that Verizon Wireless operates at maximum capacity, and with the maximum possible transmitter power in each band.

The table that follows outlines the proposed antenna information:

700 MHz Antenna Data	
Antenna Model (Max. Gain)	Amphenol HTXC033S17R000G (16.6 dBi) Amphenol HTXC4517R000G (16.4 dBi)
RF Channels per Sector	1
Transmitter Power / RF Channel	40 watts
850 MHz Antenna Data	
Antenna Model (Max. Gain)	Amphenol HTXC033S17R000G (17.1dBi) Amphenol HTXC4517R000G (16.9 dBi)
RF Channels per Sector	8
Transmitter Power / RF Channel	20 watts
1900 MHz Antenna Data	
Antenna Model (Max. Gain)	Amphenol WBX033T20R000G (19.5 dBi) Amphenol WBX045T19R000G (18.5 dBi)
RF Channels per Sector	4
Transmitter Power / RF Channel	16 watts
2100 MHz Antenna Data	
Antenna Model (Max. Gain)	Amphenol WBX033T20R000G (20 dBi) Amphenol WBX045T19R000G (19 dBi)
RF Channels per Sector	2
Transmitter Power / RF Channel	40 watts

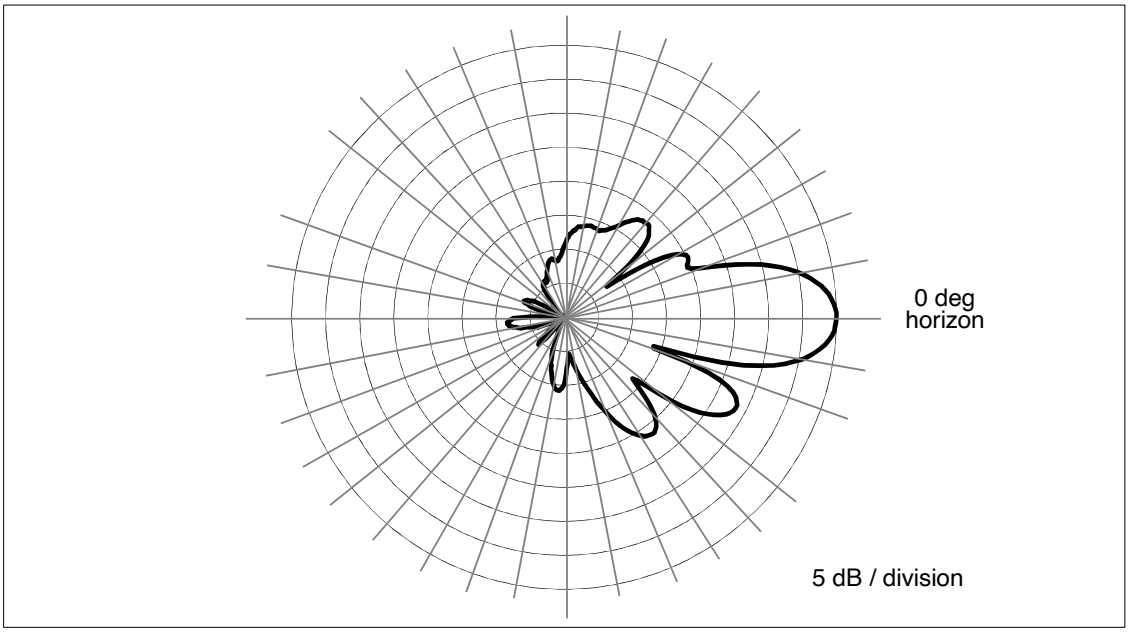
The Verizon Wireless antennas are to be mounted on the perimeter of a rooftop bulkhead. The Alpha sector antennas will have a centerline height of 178 feet 10 inches. The Beta and Gamma antenna sectors will have a centerline height of 171 feet 8 inches.

Panel antennas exhibit significant directionality (signal-focusing) characteristics in both the horizontal and vertical planes. Almost all of the RF energy is directed toward the horizon in front of the antenna, and very little energy is emitted to the side, to the rear, or below the antenna.

By way of illustration, Figure 1 that follows shows the vertical-plane radiation pattern of one of the proposed Verizon Wireless antenna models.

The relative strength of the pattern is described using decibel units. Where the discrimination reads 20 dB, the relative power is lower by a factor of 100; at 30 dB, the factor is 1,000.

Fig. 1. Amphenol HTXC033S17R000G Antenna – 700 MHz Vertical-plane Pattern



Appendix B. FCC Compliance Analyses

Background

The Federal Communications Commission (FCC) has established standards for continuous human exposure to RF fields, and this report assesses compliance with those safety standards, which are the strictest than can be applied.

The FCC's MPE limits are incorporated in Section 1.301 *et seq* of its Rules and Regulations (47 CFR 1.1301-1.1310). The basis for the RF safety limits is an understanding that excessive exposure to RF fields – that is, long-term exposure at levels well beyond a certain threshold level – can introduce a health risk. (At the same time, the FCC recognizes that the low transmitter power used by PCS and cellular antennas results in no effect on the human health environment; the RF exposure limits primarily affect the operations of other, higher-power radio transmitters.)

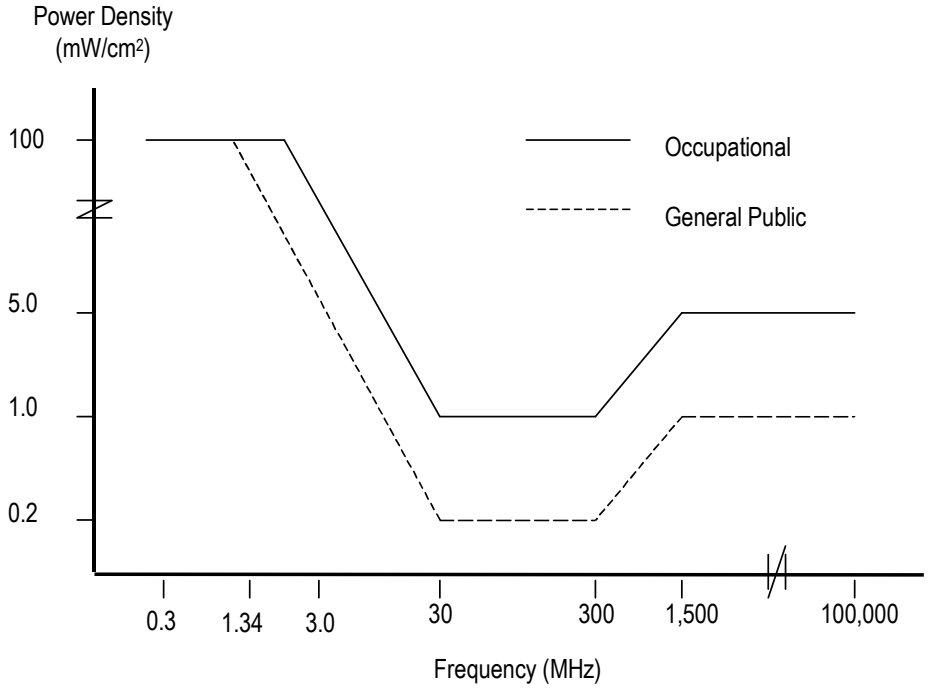
The FCC maximum permissible exposure (MPE) limits represent the consensus of federal agencies and independent experts responsible for RF safety matters. Those agencies include the National Council on Radiation Protection and Measurements (NCRP), the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), the American National Standards Institute (ANSI), the Environmental Protection Agency (EPA), and the Food and Drug Administration (FDA).

The FCC MPE limits for the general public are based on: (1) the known ability of the human body to safely dissipate energy from sources of different RF frequencies; and (2) a safety margin of 50, built into the specified limits applicable to the general public. Because of the threshold nature of the potential health risk and the significant built-in safety factor, continuous exposure at RF levels up to and equal to the MPE limit is considered to result in no human health risk whatsoever. The limits were constructed to provide appropriate protection for humans of both sexes, all ages and sizes, and under all types of conditions.

The Occupational Safety and Health Administration (OSHA) requires employers to provide RF safety training for individuals whose work brings them into frequent contact with antenna sites. Related to that safety-training requirement, the FCC regulations include a second, slightly relaxed set of MPE limits that are applicable to individuals who: (1) are aware of the existence of antennas; (2) understand the potential health risk; and (3) use their training to safely control the potential exposure. The FCC's so-called "occupational" MPE limits incorporate a safety margin of 10 (as opposed to the margin of 50 for the general public). Fundamentally, the "uncontrolled" limit applies to areas of unrestricted public access, and the "controlled" limit applies elsewhere.

The FCC's RF exposure limits are expressed in the form of power density – essentially power divided by area, expressed in units of milliwatts per square centimeter, or mW/cm^2. The table and diagram on the next page describe the FCC limits for both occupational and general public exposure to RF levels in the specified frequency ranges.

Frequency Range (F) (MHz)	Occupational Exposure (mW/cm^2)	General Public Exposure (mW/cm^2)
0.3 - 1.34	100	100
1.34 - 3.0	100	$180 / F^2$
3.0 - 30	$900 / F^2$	$180 / F^2$
30 - 300	1.0	0.2
300 - 1,500	F / 300	F / 1500
1,500 - 100,000	5.0	1.0



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FCC Mathematical Models and Compliance Analyses

FCC Office of Engineering and Technology Bulletin 65 ("OET Bulletin 65") provides guidelines for applying various mathematical models to calculate potential RF exposure levels at various points around transmitting antennas.

Far-Field Model and Calculations

The "far-field" model is used for calculating the street-level exposure. The FCC "far-field" mathematical formula considers the RF power emitted by the antennas, the antennas' vertical-plane emission pattern characteristic and the straight-line distance to the point of interest.

The "far-field" formula is as follows:

$$MPE\% = (100 * TxPower * 10^{(Gmax-Vdisc)/10} * 4) / (MPE * 4\pi * R^2)$$

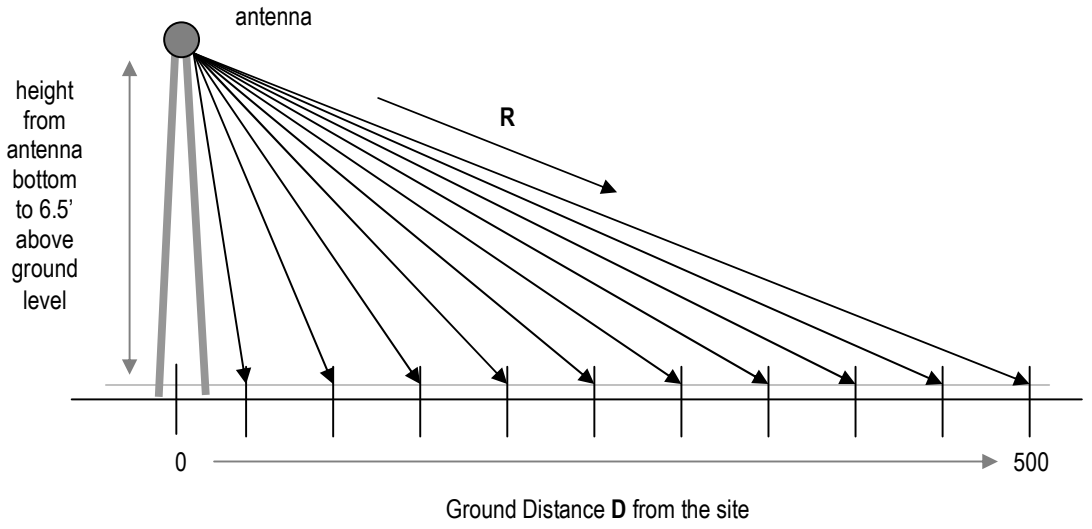
where

MPE%	=	RF level, expressed as a percentage of the FCC general population ("uncontrolled") MPE limit
100	=	factor to convert to a percentage
TxPower	=	maximum power into antenna, milliwatts
$10^{(Gmax-Vdisc)/10}$	=	numeric equivalent of the relative antenna gain in the downward direction of interest
4	=	the factor to account for a 100-percent-efficient energy reflection from the ground, and the squared relationship between RF field strength and power density ($2^2 = 4$)
MPE	=	FCC general population MPE limit
R	=	straight-line distance from the RF source to the point of interest, centimeters

There are a number of built-in aspects to all of the calculations that assure very "safe-side" results and conclusions regarding RF compliance. These include an assumption that the antennas are operated at full (maximum) power on a continuous basis, when in fact the antennas operate with considerably less power on average.

The conservative approach taken here is specifically intended to overstate the calculated exposure levels versus those that will actually occur from the antenna operation, so if the calculations show compliance with the FCC MPE limit, we can have great confidence that the antenna operation will indeed comply with that limit.

Street-level compliance calculations are performed from the bottom of the antenna to the top of an assumed 6'6" human – conservatively minimizing the straight-line distance in the FCC formula – and the calculations are done out to a horizontal distance of 500 feet from the site. (See the illustrative diagram below.)



Street-level MPE% Compliance Calculation Geometry

Note that while it may be popularly assumed that the farther away one is from an antenna, the lower should be the RF level – that is not universally true. The results of MPE% calculations as one hypothetically moves away fro a site reflect the variations in the vertical-plane antenna pattern as well as the progressive increase in the straight-line distance to the antennas. Therefore, fairly close to the site the RF levels may actually increase slightly with increasing distance within the range of zero to 500 feet from the site. As the distance approaches 500 feet, though, the antenna pattern factor becomes less significant, the RF levels become primarily distance-controlled, and as a result the RF levels generally decrease with increasing distance (and are well understood to be comfortably in compliance).

FCC compliance for a multiple-band antenna operation is assessed in the following manner. At each distance point along the ground, an MPE% calculation is made for the RF effect in each frequency band, and the sum of the individual MPE% contributions at each point is compared to 100 percent, which serves as the normalized reference for the FCC MPE limit. We refer to the sum of the individual MPE% contributions as "total MPE%", and any calculated MPE% total MPE% result exceeding 100 percent is, by definition, higher than the FCC limit and represents non-compliance and a need to mitigate the RF levels. If, on the other hand, all results are below 100 percent, that set of results serves as a demonstration of compliance with the MPE limit.

The table below lists the street-level calculation results out to 500 feet from the site, with the overall maximum (worst-case) result highlighted in bold.

Ground Dist (ft)	**Verizon 700 MHz MPE%**	**Verizon 850 MHz MPE%**	**Verizon 1900 MHz MPE%**	**Verizon 2100 MHz MPE%**	**Total MPE%**
0	0.0047	0.0034	0.0264	0.0054	0.0399
20	0.0016	0.0021	0.0327	0.0082	0.0446
40	0.0033	0.0017	0.0261	0.0160	0.0471
60	0.0090	0.0016	0.0137	0.0192	0.0435
80	0.0227	0.0098	0.0185	0.0260	0.0770
100	0.0382	0.0337	0.0130	0.0182	0.1031
120	0.0439	0.0705	0.0046	0.0085	0.1275
140	0.0317	0.0864	0.0069	0.0158	0.1408
160	0.0125	0.0594	0.0023	0.0127	0.0869
180	0.0266	0.0263	0.0106	0.0149	0.0784
200	0.0470	0.0189	0.0057	0.0398	0.1114
220	0.0708	0.0544	0.0016	0.0091	0.1359
240	0.0794	0.1013	0.0058	0.0081	0.1946
260	0.0815	0.1648	0.0053	0.0135	0.2651
280	0.0783	0.2290	0.0116	0.0063	0.3252
300	0.0774	0.2781	0.0102	0.0023	**0.3680**
320	0.0653	0.2886	0.0043	0.0020	0.3602
340	0.0540	0.2618	0.0017	0.0002	0.3177
360	0.0418	0.2276	0.0008	0.0011	0.2713
380	0.0304	0.1941	0.0026	0.0043	0.2314
400	0.0197	0.1514	0.0051	0.0124	0.1886
420	0.0112	0.1131	0.0072	0.0160	0.1475
440	0.0046	0.0738	0.0065	0.0166	0.1015
460	0.0039	0.0430	0.0044	0.0116	0.0629
480	0.0058	0.0205	0.0010	0.0048	0.0321
500	0.0054	0.0190	0.0009	0.0045	0.0298

As indicated, the worst-case calculated street-level RF effect at any distance is 0.3680 percent of the FCC limit. This result represents compliance by a factor of more than 270.

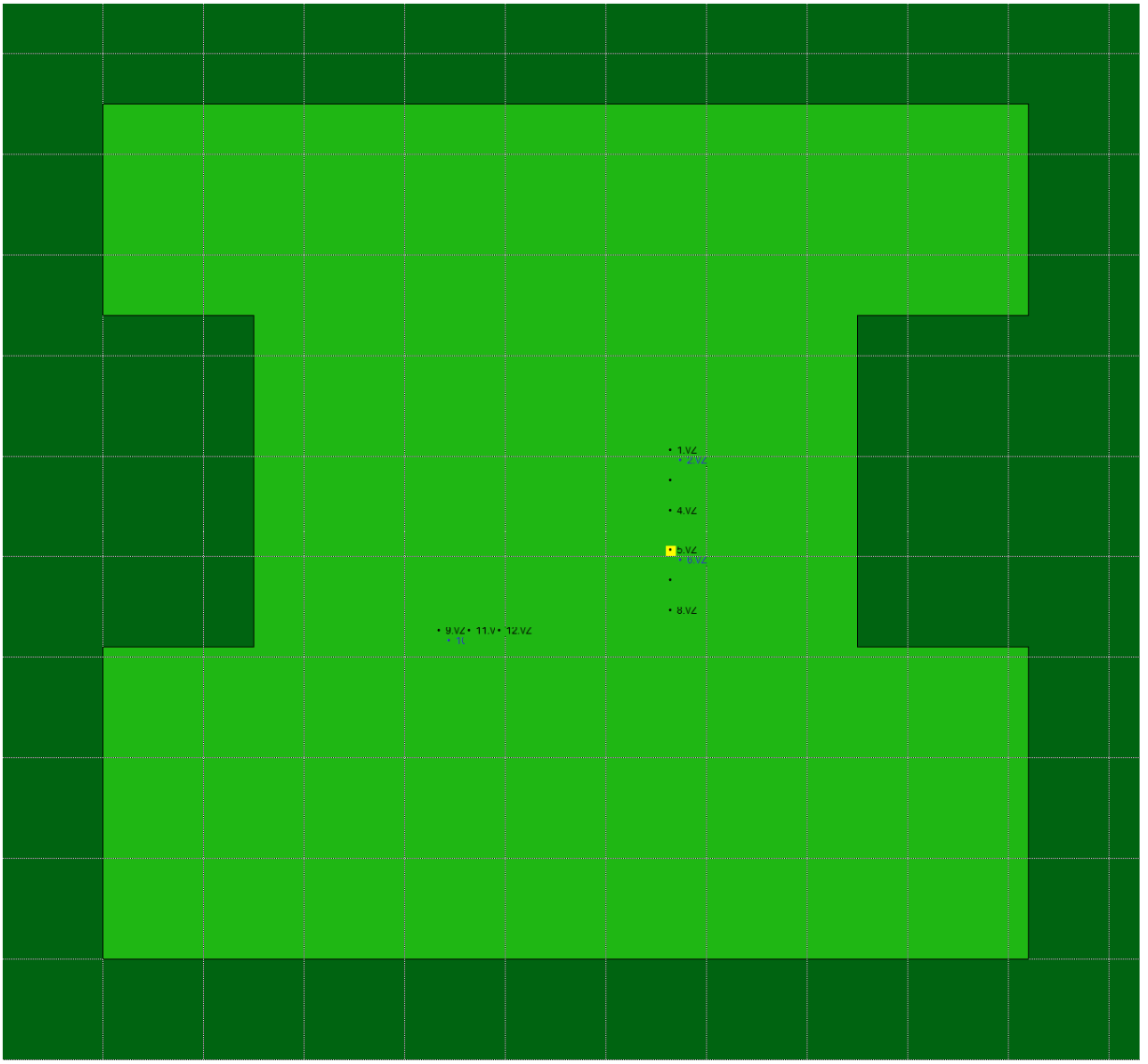
Analysis for the Rooftop Near the Antennas

In order to assess the RF levels on the roof, we relied on a commercially-available software package called “RoofView®”, from Richard Tell Associates.

The program’s primary output is a graphic, color-coded depiction of the RF levels in the area near antennas. A standard green/yellow/red color coding is used to illustrate areas subject to calculated RF levels satisfying the FCC general population limit (green), exceeding the occupational MPE limit (red), or RF levels between those extremes (yellow).

Note that any color-coding of the boxes identifying antenna locations (black dots) represents a “divide-by-zero-distance” anomaly in the software and is not significant. Note, too, that in a grayscale printout, the color green appears as a medium gray, yellow is a light gray, and red is a very dark gray.

The graphic output of the *RoofView* program is reproduced below.



As indicated by the all-green color-coding, there are no areas that exceed the FCC general population MPE limit.

We used the “spot-calculation” feature of the *RoofView* program to quantify the maximum RF level on the roof. In front, and to the side of, the Verizon Wireless Beta sector antennas, the calculated RF level is 95.25 percent of the FCC general

population MPE limit (which is equivalent to 19.05 percent of the FCC occupational MPE limit).

Analysis of "RF Leakage" Into the Building

Small amounts of RF energy can pass through obstructions like a rooftop or building walls, which is the way we routinely receive broadcast TV and radio signals in our homes. The same is true for cellular radio signals, and we call the effect "RF leakage".

The calculations of "RF leakage" into the building from the rooftop antennas are conservatively performed at ceiling height inside the building, at a position directly underneath any one of the antenna sectors.

Recall from the antenna pattern diagrams that most of the RF energy is emitted in the horizontal direction. The minimum pattern discrimination directly downward is more than 20 dB.

As a result, the maximum RF leakage from the rooftop-mounted antennas is 0.0713 percent of the FCC limit – a clear demonstration of compliance. Moreover, the RF levels are progressively lower farther away from the antennas, that is, anywhere else lower in the building.

Compliance Conclusion

The result of these analyses is that the RF emissions from the antenna operations at this site will be in compliance with the strictest, most protective FCC MPE limit at street level around the site, on the rooftop, and inside the building.

Appendix C. Summary of Expert Qualifications

Daniel J. Collins, Chief Technical Officer, Pinnacle Telecom Group, LLC

Synopsis:	• 40+ years of experience in all aspects of wireless system engineering, related regulation, and RF exposure • Has performed or led RF exposure compliance assessments on more than 17,000 antenna sites since the latest FCC regulations went into effect in 1997 • Has provided testimony as an RF compliance expert more than 1,400 times since 1997 • Have been accepted as an FCC compliance expert in New York, New Jersey, Connecticut, Pennsylvania and more than 40 other states, as well as by the FCC
Education:	• B.E.E., City College of New York (Sch. Of Eng.), 1971 • M.B.A., 1982, Fairleigh Dickinson University, 1982 • Bronx High School of Science, 1966
Current Responsibilities:	• leads all PTG staff work involving RF safety and FCC compliance, microwave and satellite system engineering, and consulting on wireless technology and regulation
Prior Experience:	• Edwards & Kelcey, VP – RF Engineering and Chief Information Technology Officer, 1996-99 • Bellcore (a Bell Labs spinoff after AT&T's 1984 divestiture), Executive Director – Regulation and Public Policy, 1983-96 • AT&T (Corp. HQ), Division Manager – RF Engineering, and Director – Radio Spectrum Management, 1977-83 • AT&T Long Lines, Group Supervisor – Microwave Radio System Design, 1972-77
Specific RF Safety / Compliance Experience:	• Involved in RF exposure matters since 1972 • Have had lead corporate responsibility for RF safety and compliance at AT&T, Bellcore, Edwards & Kelcey, and PTG • Have been relied on for compliance by all major wireless carriers, the federal government, several state and local governments, other wireless operators, system integrators, and other consulting / engineering firms
Other Background:	• Author, *Microwave System Engineering* (AT&T, 1974) • Co-author and executive editor, *A Guide to New Technologies and Services* (Bellcore, 1993) • National Spectrum Managers Association (NSMA) – former three-term President and Chairman of the Board of Directors; earlier was founding member, twice-elected Vice President, long-time member of the Board, and was named an NSMA Fellow in 1991 • Have published more than 35 articles in industry magazines