RLH Industries, Inc.

GPR Engineering Services

GPR Studies

Prepared for:

123 Wireless Communications, Inc

123 Wireless Project Number: XXXXX318

123 Wireless Number: XXXXX2478

MD-016 2012A-0506

GPR Analysis

Introduction

This is a report of the Ground Potential Rise (GPR) analysis conducted for 123 Wireless Communications, inc. in the New York market build-out. 123 Wireless has proposed placing 5 of their BTS sites on Mega Watt Power Company's high-voltage transmission towers. This constitutes potentially hazardous environments due to the presence of GPR during a power fault at or near these sites. To accommodate this hazardous environment, it is proposed to place fiber-optic isolation equipment manufactured by RLH Industries, Inc. for the last leg of the facility entering the BTS site.

This specific site is 123 Wireless site number (xxxxxx2478), located at 123 Anywhere Road, in Any Town, NY. The location is in a close residential area with modern homes constructed on the West side of the tower route right-of-way (ROW) and several apartment buildings bordering along the East side of the ROW. The ROW is approximately 150 feet wide with three HVI routes paralleling one another up and down the ROW in a generally north/south orientation. These routes are one double 345 KV route (upon which, the proposed 123 Wireless site is located) and two double 138 KV routes aligned to the West of the 123 Wireless tower. The tower in consideration is specifically located just North of the fields which border on Smith Road. Below is a satellite photograph of the site with denotation of the tower under test, as well as the recommended location for the copper-fiber-junction (CFJ).

***Figure 1**. Satellite View of Site*

Executive Summary

The results of the study indicate the following:

- Measured value of Zone of Influence (ZOI) = 100 Feet
- GPR Study evaluation of ZOI to 300 volt point to South = 100 feet

Study Details

The study consists of several segments. The first segment was performed collecting on-site data regarding some general information about the site and its grounding. Earth resistivity measurements were performed in the region to determine the facts regarding multiple level resistivity scenarios. The results of the resistivity study indicate that there is relatively low resistivity in this region, measuring in the 30 to 37 Meter-Ohm range.

Next, the study conducted a fall-of-potential measurement of the ground grid at the tower site. The results of this study is shown below. This measurement was done with the C2 probe located 750 feet away from the ground under test (GUT). This put the C2 probe out to Smith Road near the Southwest corner of the high voltage right-of-way (ROW), then down the sidewalk, well past a row of houses with multiple underground utility appearances. The C2 probe was kept at least 10 feet away from any MGN ground connection in the vicinity in order to avoid any incidental influence from the neutral system during the test. The fall-of-potential (FoP) readings are shown below, with their resultant graphical representation.

P2 Distance	Resistance
2	0.85
10	1.04
20	1.23
30	1.36
40	1.36
50	1.38
100	1.5
125	1.5
150	1.5

Figure 2. *FoP Data Points*

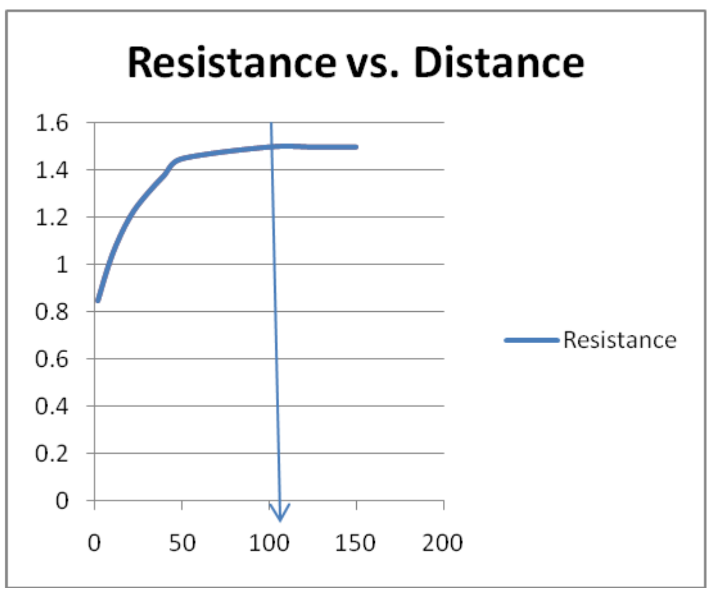

Figure 3. *Resistance vs. Distance Chart*

Plotting the FoP data on a graph identifies a curve that shows how the resistance gradient measured also can be used to define the edge of the ZOI. In this instance, the resistance levels off at approximately 100 feet from the GUT. What this means is that considering all other factors, and regardless of the amount of current flowing through the GUT, no additional significant resistance will be contributed to the GPR profile with additional distance from the grid.

Additional GPR study was also performed for the site using SES Autogrid Pro software. This software takes into consideration many more details of the grounding and GPR scenario that we are faced with compared with the average GPR calculating software.

The scenario that is presented for the GPR study is comparable to that which is typically accommodated by power companies and telcos. It assumes that the tower is independent from any other connections to any other metallic distribution network (intentional or incidental). The parameters of the system are input, and any influence from external grounding effects are ignored. The grounding system that was modeled incorporates the tower ground plus an adjacent grid beneath the BTS equipment enclosure. Fig. 4 shows the grounding system that was modeled for the study.

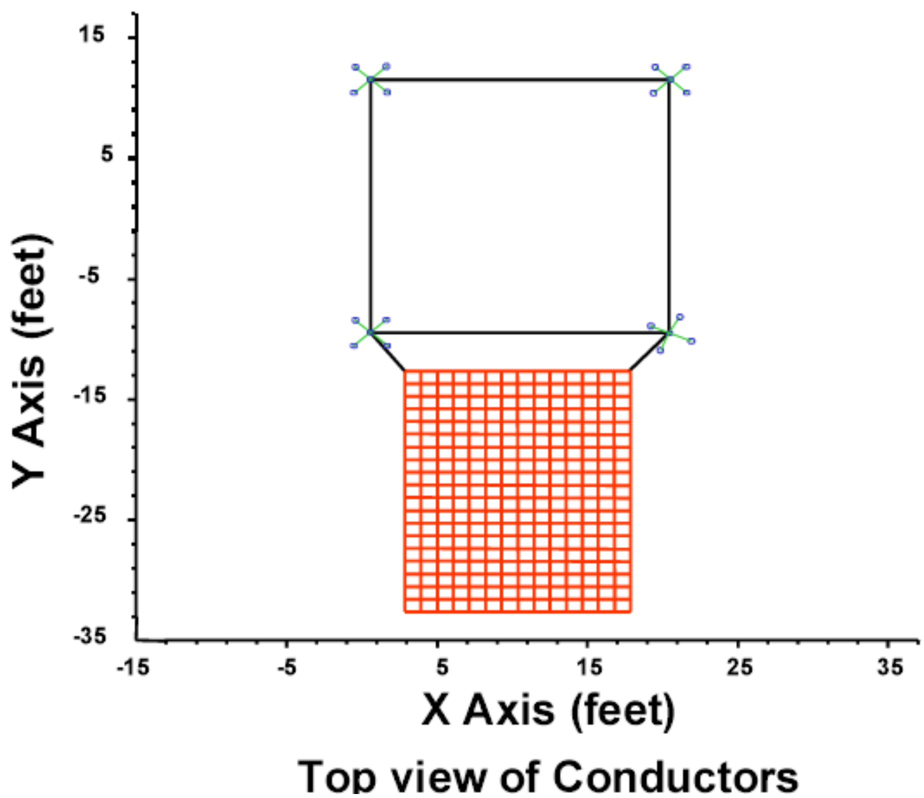

Figure 4. *Layout of Site Grounding Modeled*

The source of data that was input is Johnny Appleseed, P.E., Senior Engineer, Mega Watt Power Company, Any Town, NY, and the software used is AUTOGRID PRO - SES (Safe Engineering Services & Technologies Ltd.)

The input data for the software is as follows.

Shunt Potential (GPR) Magnitude (Volts)
Shunt Potential One Terminal Plot
GPR (Shunt Potential) for each HV tower back to the SOURCE substation

===========< G R O U N D I N G (SYSTEM INFORMATION SUMMARY) >===========
Run ID ....: SINGLE TOWER ONLY (3
System of Units ....: Feet
Earth Potential Calculations ....: Single Electrode Case
Type of Electrodes Considered......................................: Main Electrode ONLY
Soil Type Selected ....: Multi-Layer Horizontal
SPLITS/FCDIST Scaling Factor ....: 5.0024
MULTI-LAYER EARTH CHARACTERISTICS USED BY PROGRAM
LAYER TYPE REFLECTION RESISTIVITY THICKNESS

No.	COEFFICIENT	(ohm-meter)	(FEET)
1 Air	0.00000	0.100000E+21	Infinite
2 Soil	-0.999990	35.9341	0.657408
3 Soil	-0.100016	29.3997	Infinite

CONFIGURATION OF MAIN ELECTRODE
================================
Original Electrical Current Flowing In Electrode..: 1000.0 amperes
Current Scaling Factor (SPLITS/FCDIST/specified)..: 5.0024
Adjusted Electrical Current Flowing In Electrode..: 5002.4 amperes
Number of Conductors in Electrode.................: 71
Resistance of Electrode System....................: 1.2404 ohms

SUBDIVISION
===========
Grand Total of Conductors After Subdivision.: 769
Total Current Flowing In Main Electrode......: 5002.4 amperes
Total Buried Length of Main Electrode........: 874.14 feet

The results of the program analysis indicate the following:

EARTH POTENTIAL COMPUTATIONS

Main Electrode Potential Rise (GPR) : 6204.9 volts

GPR 300 volt point : North = 106' South = 100' East = 110' West = 112'

Fault Analysis

A schematic of the fault is shown in Figure 5, below with the affects of multiple tower grounding taken into consideration, along with the impedances of the source and remote substations.

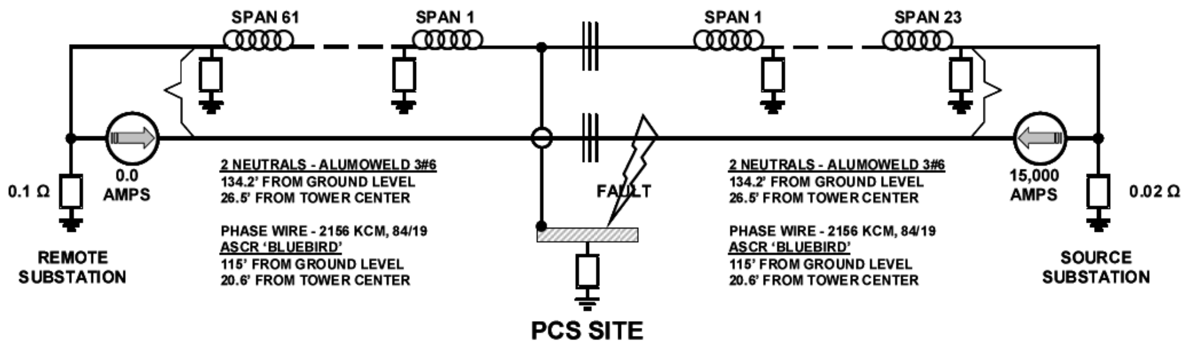

Figure 5. *Fault Grounding Schematic*

The GPR that is inherent to the tower under test is also felt, though to lesser degree, at adjacent towers as indicated in Figure 6. There are 23 spans between the tower being modeled and the source substation.

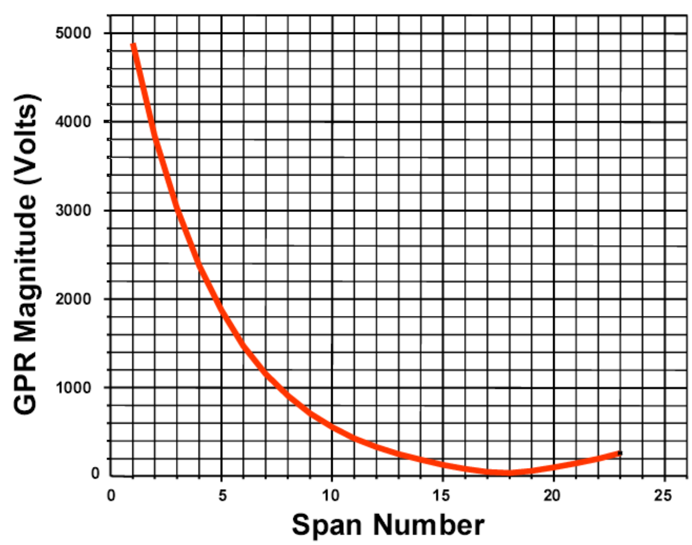

Figure 6. *GPR (Shunt Potential) for each HV tower back to the SOURCE substation*

Figure 7 below shows a detailed overview of the GPR profile, with a 3-dimensional graph of the GPR shown in Fig. 8.

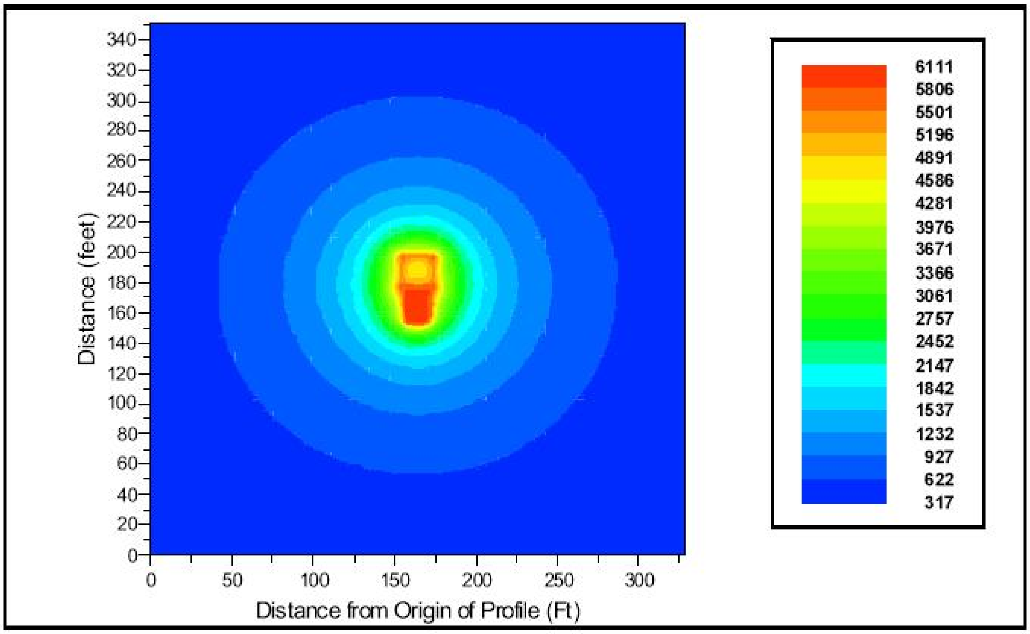

Figure 7. *GPR Profile (North is Up)*

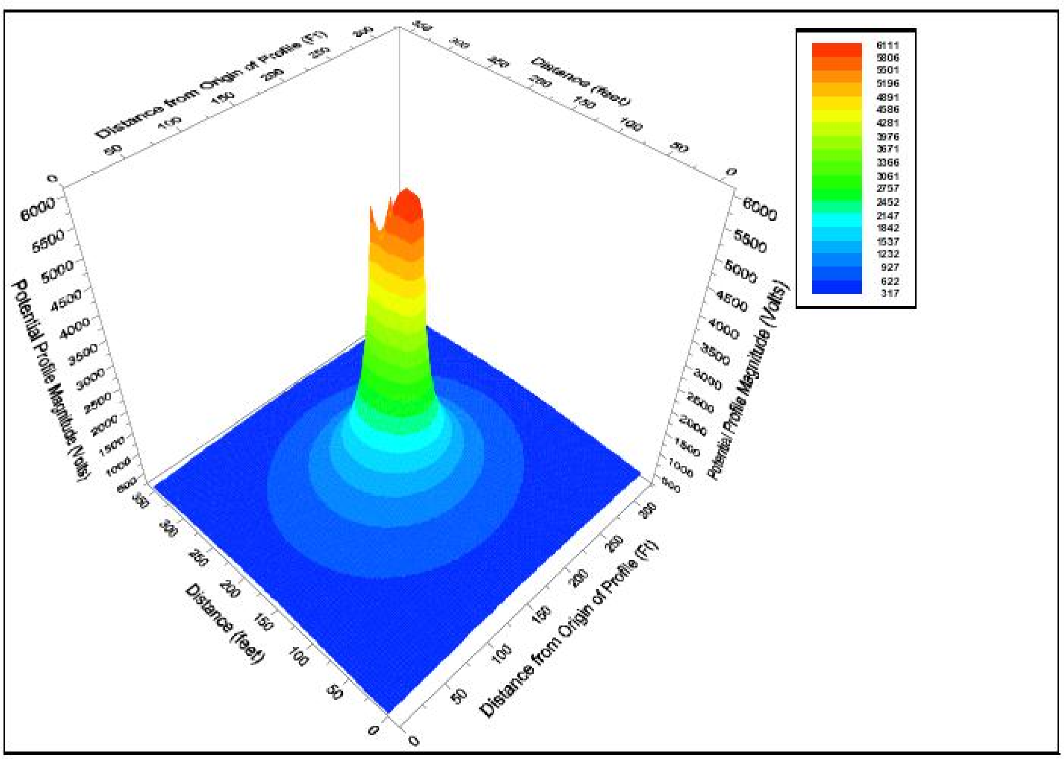

Figure 8. *GPR Profile in 3-D*

One notes from this graph that the GPR is high, but the zone-of-influence is relatively small. It is also notable that this ZOI is comparable to the measured ZOI of Figure 3.

If this tower were to remain isolated from any other infrastructure, this might represent reality to some respectable degree of accuracy, but in the real world, there are issues such as direct and indirect bonding to other metallic structures that influence the GPR profile significantly. Please refer to the addendum attached to this study which addresses some of the issues associated with real-world structures and their effects on GPR issues.

Conclusion

The final analysis of this study demonstrates that the GPR evident at this site can be accommodated and isolated from the Telco Network by the application of a fiber optic high-voltage isolation system, such that the CFJ (copper-fiber junction) is located a minimum of 100 feet from the tower grounding system.

From a pragmatic perspective, it is recommended, however, that the fiber be run to a point in proximity to the first access point to the telco network which would be along Smith Road. At that point, the telco can bring their copper facilities, either cable or drop, into the RLH pedestal or cabinet provided. It is advisable to place a 3-rod ground bed in a “ring” format around or adjacent to the pedestal using standard ring-design techniques as recommended by the local telco.

It should be noted, as a matter of course, that the GPR scenario identified is independent of any connections of the RLH equipment to the network. In this situation, serving the pedestal is tantamount to serving a non-high voltage customer.

Addendum: Additional Study Considerations

The GPR study presented in this report ignores the affects of intentional and incidental bonds between the tower and other grounding or grounded systems in the vicinity. Some of these influences are the result of buried and aerial utilities, such as power distribution, metallic water lines, gas lines, and metallic communication cables (telephone and CATV). Variations to the study can also be affected by bodies of surface water, such as rivers and streams. It is not practical to model every one of the influences on realistic GPR profiles, but it can be shown how just one of the considerations of reality can have a large effect on the GPR profile.

For the purpose of this additional study, I have modeled the MGN system around the tower to get a representation that is more closely tied to reality. The GPR profile of the surrounding metallic infrastructure is a function of earth resistivity and the fault current entering the PCS grid. The modeling has been kept fairly simple and not included anything other than the effects of bonding the power distribution MGN system and that only extending this influence for a block or so of the tower in each direction. Figure A1 shows the modeling of the MGN system in the immediate vicinity of the tower.

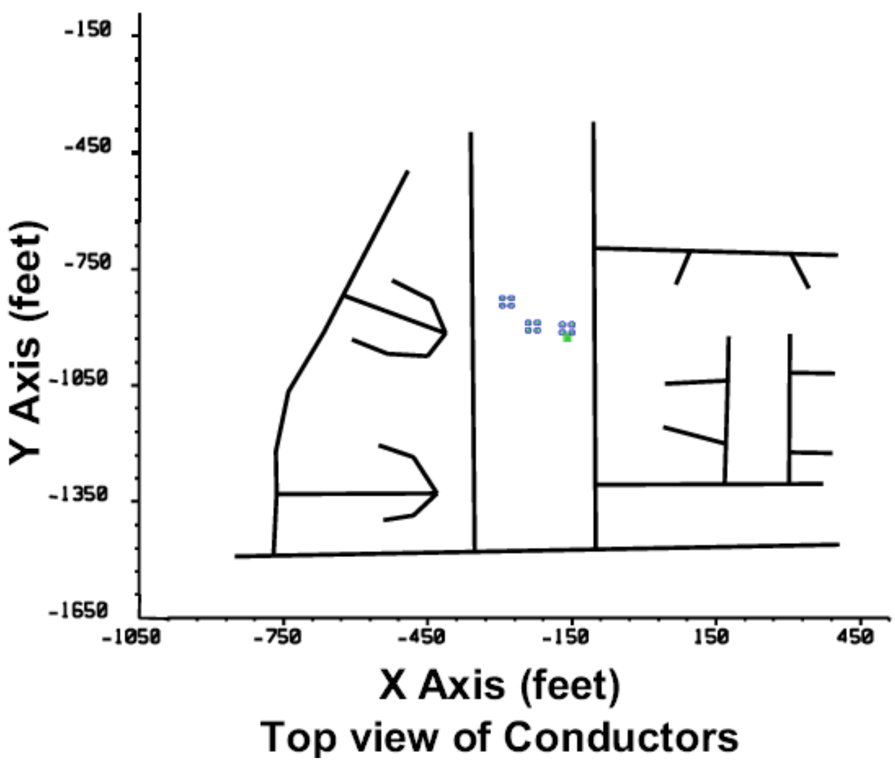

Figure A1. *MGN Modeling of the Vicinity*

The program settings for the expanded GPR model are as follows

===========< G R O U N D I N G (SYSTEM INFORMATION SUMMARY) >===========

Run ID......................................: PCS ON COMMUNITY MGN

System of Units ....: British

Earth Potential Calculations................: Single Electrode Case

Type of Electrodes Considered..............: Main Electrode ONLY

Soil Type Selected..........................: Multi-Layer Horizontal

SPLITS/FCDIST Scaling Factor................: 17.673

MULTI-LAYER EARTH CHARACTERISTICS USED BY PROGRAM

LAYER TYPE No.	REFLECTION COEFFICIENT	RESISTIVITY (ohm-meter)	THICKNESS (FEET)
1 Air	0.00000	0.100000E+21	Infinite
2 Soil	-0.999990	35.9341	0.657408
3 Soil	-0.100016	29.3997	Infinite

CONFIGURATION OF MAIN ELECTRODE

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Original Electrical Current Flowing In Electrode..: 1000.0 amperes

Current Scaling Factor (SPLITS/FCDIST/specified)..: 17.673

Adjusted Electrical Current Flowing In Electrode..: 17673. amperes

Number of Conductors in Electrode.................: 169

Resistance of Electrode System....................: 0.057717 ohms

SUBDIVISION

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Grand Total of Conductors After Subdivision.: 1383

Total Current Flowing In Main Electrode......: 17673. amperes

Total Buried Length of Main Electrode........: 9350.3 feet

The results of the software calculations and computations are as follows:

EARTH POTENTIAL COMPUTATIONS

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Main Electrode Potential Rise (GPR) : 1020.0 volts

GPD (Ground Potential Difference) between PCS
and Smith Road AT&T access terminal (a distance of 561’) = 142 volts

The result of this inclusion renders a much more complicated scenario as depicted in Figure A2.

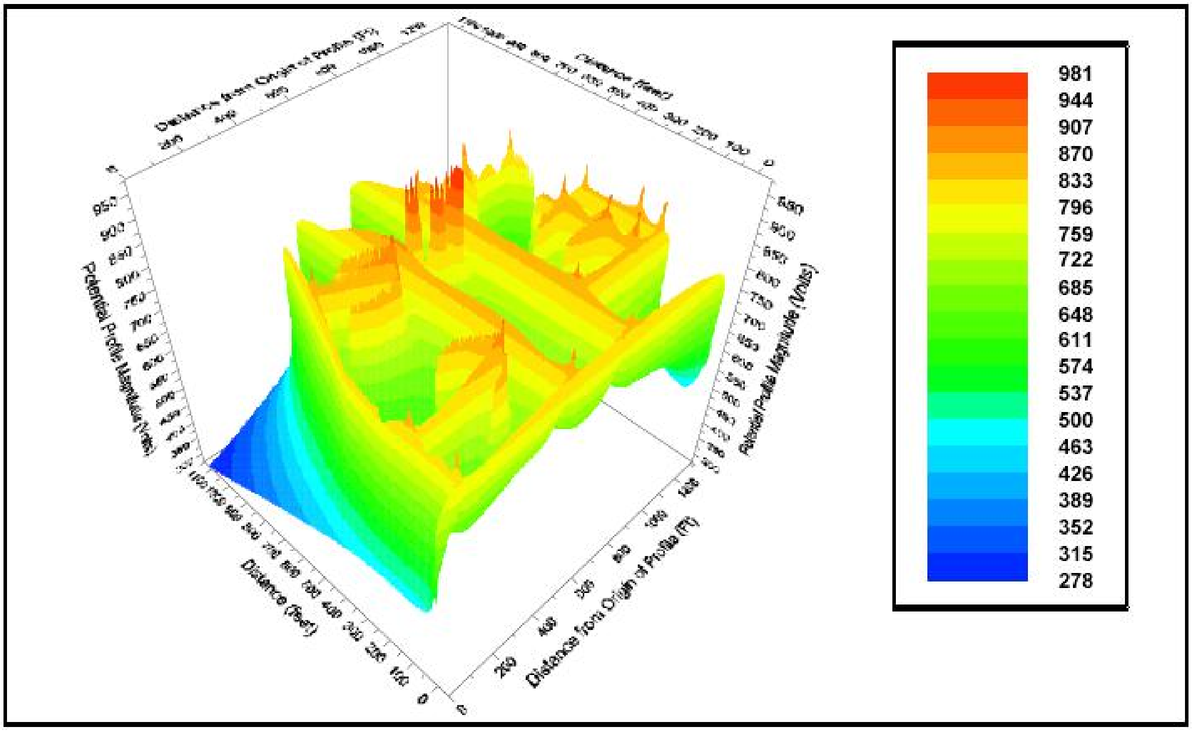

Figure A2. *GPR Profile with Limited MGN Connections Identified*

This 3-dimensional graph shows the effects of the inclusion of the particular MGN routings for this area. Inclusion of a broader range was not advisable due to the fact that the addition of so many data points would have made the calculations much more cumbersome.

That said, it is evident from this graph that the inclusion of these other considerations has done two things that are most predominant. First, it has reduced the GPR to a value that is less than 1000 Volts (RMS-Assymetrical), but it has also increased the sphere of influence out into the neighborhood, such that close to Smith Road, the GPR only drops down to 685 Volts or so at the lowest value along the route. See Fig A3 for a 2-dimensional, overhead view of the same GPR profile.

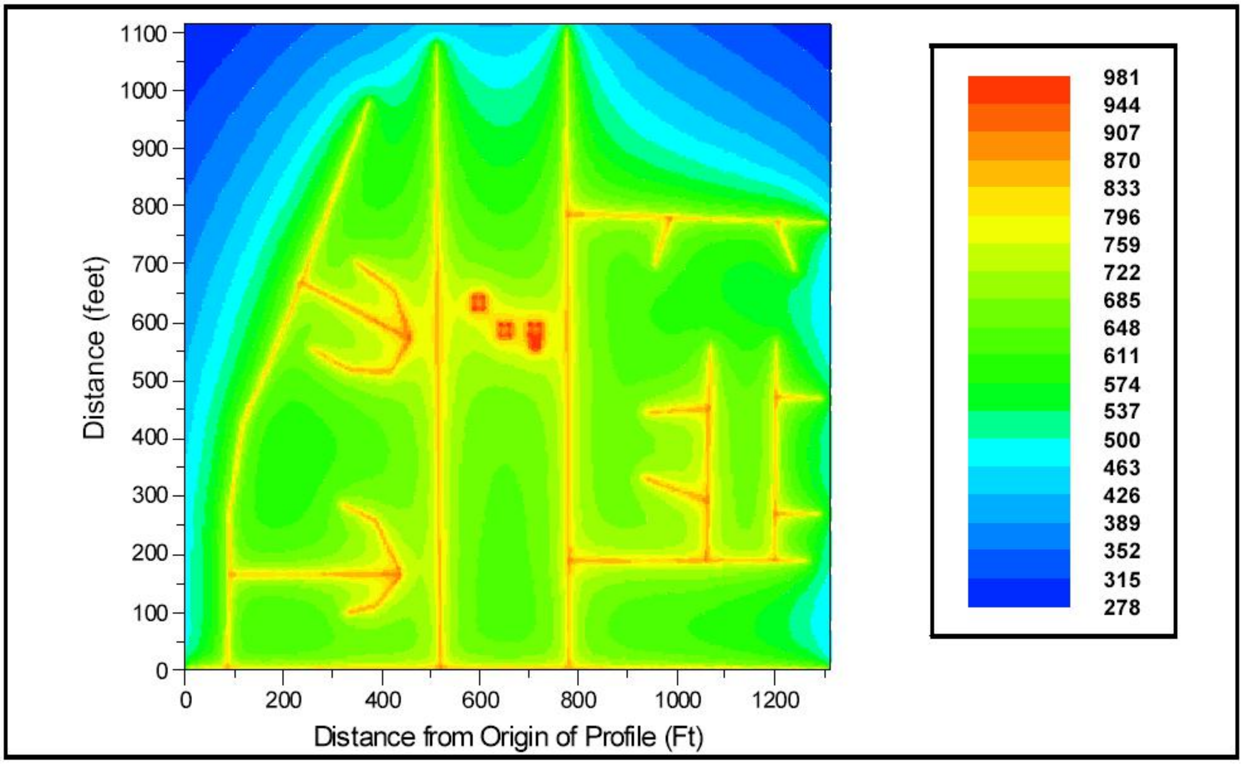

Figure A3. *Overhead Perspective of the GPR Profile*

At first, the casual observer will have an instinctive reaction concerning the location of the 300 volt point. We must keep in mind, however, that in reality, the value to pay attention to is not ground potential rise, but rather ground potential difference (GPD). Taking this into consideration, it becomes evident that the GPD stays under 300 volts once you get away from the *immediate area* of the tower ground under test.

Although the GPR profile becomes significantly more complicated when the additional bonding and grounding is introduced into the calculations, the end result is still valid. There is still only a short distance of influence. The application of a fiber optic interface, such as RLH's Fiber Optic Link, fully eliminates the introduction of transferred potentials from the faulted tower to the telco network due to the communications facilities. It also provides **total dielectric isolation** between the two systems.