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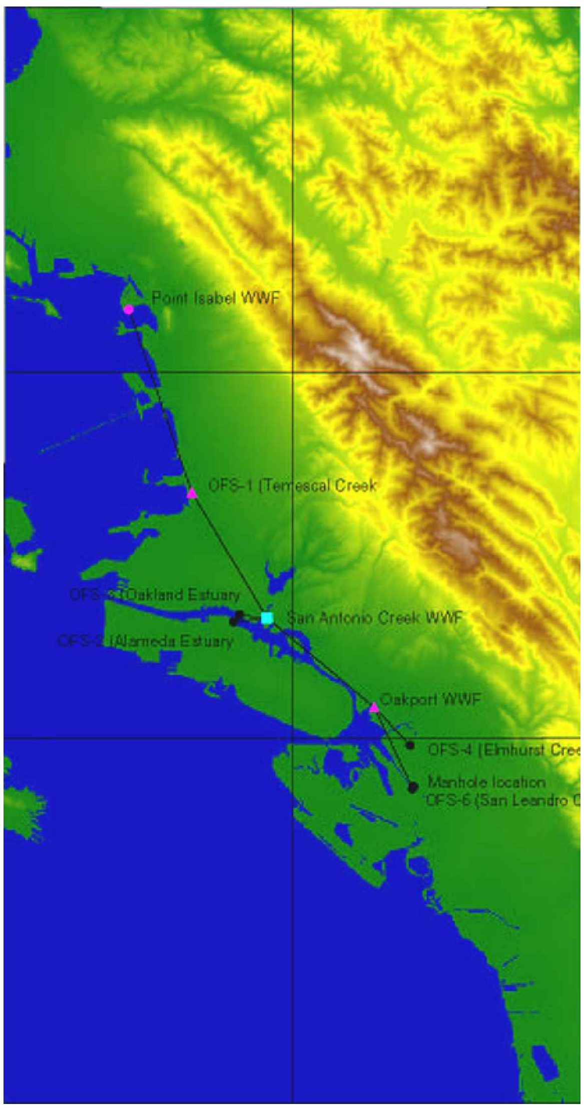
**ICL SCADA Tech Note**

# Understanding your GPS Radio Path Survey

*You had a GPS Radio Path Survey done, and now it's on your desk. What does it mean? This is a laymans guide to understanding a radio path survey.*




OK. You've done the "right thing". You're planning out a wireless SCADA system and checking it out "on paper" first with a **GPS Radio Path Survey**. You submitted the GPS data. Now the study is on your desk. What does it mean? This Tech Note is a brief guide to interpreting a radio path survey.

## What the study includes

A Radio Path Study evaluates the signal loss and resulting operating margins for every radio signal path in your system. As part of this study, you receive three types of documents:

P **Color "topo" map**

A color topological map shows each of your radio sites and interconnecting paths, overlaid on a computer generated image of the surrounding terrain and bodies of water.

P **Path Reports**

These are tabular text reports for EACH radio path, showing the position and antenna height information that you supplied, followed by the equipment used for analyzing the radio paths and the resulting calculated signal strengths and margins.

P **Elevation Views**

Elevation views graphically profile EACH radio path, showing a side view of the terrain that the radio signals must traverse. This can be used to help understand the radio path report results.

## The "topo" map

The topological (topo) map shows an overview of your system layout based on GPS latitude and longitude readings taken at each proposed site along with digital mapping data.

The digital mapping data resolution varies depending on the part of the world that the proposed system is to be installed. In the United States, the mapping data is typically accurate to less than 10 meters (33ft.), but international locations may have less accurate mapping data with accuracies of about 1 Km or so. The risk in these situations is that the computer could possibly "put" a site on the opposite side of a steep ridge that could alter the actual radio performance. It's always a good idea to check the topo map printout against reality, especially outside of the United States. Also, be sure to check the map for physical features that you recognize. A data entry or calculation error made while converting the GPS readings can result in "gross" errors in the system layout. The topo map can make these errors obvious.

Remember that the computer will only calculate the performance of the paths shown, so be sure that the topo map shows the "connections" the way you want them. Most systems have a central "Master" site and this is shown on the topo map as a blue box. Sites that are acting as repeaters are shown with red triangles. Paths that "work" are black lines. Paths with potential problems are shown with yellow lines.

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## Path Reports

The computer generates a report like the one below for each radio path. The reports have two columns of data, one for each end of the path.

| | | |
|---|---|---|
| Elevation (ft) | 6.56 | 11.60 |
| Latitude | 37 47 28.86 N | 37 50 03.06 N |
| Longitude | 122 15 42.24 W | 122 17 38.70 W |
| True azimuth (°) | 329.08 | 149.06 |
| Vertical angle (°) | 0.06 | -8.63E-03 |
| Antenna model | EAN0905WB | EAN0905WB |
| Antenna height (ft) | 30.00 | 30.00 |
| Antenna gain (dBi) | 7.15 | 7.15 |
| (dBd) | 5.00 | 5.00 |
| TX line type | LMR-240 | LMR-240 |
| TX line length (ft) | 30.00 | 30.00 |
| TX line unit loss (dB /100 ft) | 9.00 | 9.00 |
| TX line loss (dB) | 2.70 | 2.70 |
| Frequency (MHz) | 915.00 | |
| Polarization | Vertical | |
| Path length (mi) | 3.44 | |
| Free space loss (dB) | 106.57 | |
| Diffraction loss (dB) | 24.30 | |
| Net path loss (dB) | 121.97 | 121.97 |
| Radio model | DGRO9XXX | DGRO9XXX |
| TX power (watts) | 1.00 | 1.00 |
| (dBm) | 30.00 | 30.00 |
| Eff. Radiated Power (Watts) | 1.70 | 1.70 |
| (dBm) | 32.30 | 32.30 |
| RX Sensitivity Criteria | 10 | 10 |
| RX Sensitivity (µv) | 0.89 | 0.89 |
| (dBm) | -108.00 | -108.00 |
| RX Signal (µv) | 5.64 | 5.64 |
| (dBm) | -91.97 | -91.97 |
| RX Field Strength (µv/m) | 100.57 | 100.57 |
| Fade Margin (dB) | 16.03 | 16.03 |

Here are some of the key elements of a radio path report:

### *Elevation*

This is the site elevation based on the digital topographical mapping data and the supplied GPS coordinates.

### *Latitude and Longitude*

This is the GPS data that was entered for this path.

### *True Azimuth (°)*

This is the calculated relative position of the two radio sites, in degrees relative to True North. The difference between the two values will be approximately 180° (329 - 149).

### *Vertical Angle (°)*

This is the calculated angle from true vertical that the radio signal will travel between the sites. Since most antennas are mounted vertically instead of tilted towards the opposite site, this angle shows the error from the ideal orientation.

### *Antenna Model*

The path is evaluated using the manufacturers published specifications for specific antennas. If you don't specify the antenna model numbers, general purpose ones from Freewave Technologies will be used. Model numbers ending in "WB" are omnidirectional antennas. Model numbers ending in "YB" are directional Yagi Antennas.

### *Antenna Height*

The antenna height will typically be 10ft. for pole mounting, 15 ft. or 25ft. for roof mounting on a single story or two story building, or higher on an available tower or tank.

### *Antenna Gain*

This is a specification based on the type of antenna used. If you do not specify a gain, 5 or 6 dB antennas are used for the study, providing a good compromise between variations in terrain and coverage distance.

### *TX Line Type*

This is the antenna cable type, primarily used to calculate signal loss. LMR-240 is more flexible, but has much higher loss than LMR-400 (better), LMR-600 (much better), and Heliax (best but hard to install).

### *TX Line length (ft.)*

This is the length of the antenna cable. If you don't specify a length, it's assumed to be the same as the antenna elevation. This may not be correct if the radio is mounted away from the antenna such as in a building away from the tower or tank that supports the antenna. Try to get as close as possible, because antenna cable length can have a big effect on signal loss.

### *TX Line Unit Loss (dB/100ft.)*

This is a specification right out of the data sheets for the cable type selected above and the operating frequency. To give you an idea of the effect of cable loss, every 3dB of loss is cutting your signal in half!

### *TX Line Loss*

This is the calculated cable signal loss based on the cable type, operating frequency and cable length. In this example, it's 30ft./100ft. x 9dB = .3 x 9 = 2.70dB

### *Frequency (MHz)*

This is the operating frequency used for the calculations. For spread spectrum systems, the midpoint of the spectrum is used (915MHz for the 902 to 928MHz band).

### *Polarization*

Most people mount their antennas vertically, which is "vertical polarization". Sometimes, people mount antennas horizontally to avoid interference from vertically polarized sources, but this does not work well over hills.

### *Path length*

This is the calculated distance for the radio path "as the crow flies".

### *Free Space and Diffraction Losses*

These are the losses just from sending the signal through the air and over/around obstacles.

***Net Path Losses***

This is the sum of all losses and gains in the system; the loss through the air, the losses in the antenna cables on either end, and "gains" from the antennas on either end.

***Radio Model***

This is the model of radio being used. The study will be based on the radio manufacturer's published specifications. Since radios have varying performance characteristics, it's important to be sure that the study is done based on the actual radios being used in the system. The Freewave radios used in this study have some of the industry's best performance specifications and will provide better 'numbers" than will be realized with most other radios.

***TX Power (watts and dBm)***

This is the radios maximum RF output power, taken right from the published specifications.

***Effective Radiated Power (watts and dBm)***

This is the calculated effective radiated power based on the radios maximum output power specification and the gain of the antennas being used.

***RX Sensitivity (watts and dBm)***

This is the receiver sensitivity of the radios taken right from the published specifications. Be careful if you are not using Freewave radios. Other radios have worse sensitvity and data error rates and lower data throughputs. The Freewave radios in this study have a 1 part in $10^{-6}$ (1 bit in a million!) error rate, -108dBm sensitivity and 115K baud throughput.

***RX Signal Level (uV and dBM)***

This is the calculated signal level at the radio receiver input.

***Fade Margin***

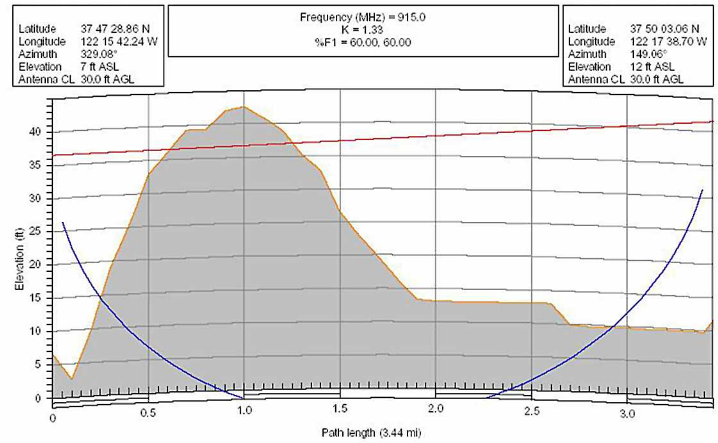
This is the amount of margin left to allow for the natural variations in radio performance that will occur, due to weather, air density, etc. Having a Fade Margin of 15dB or greater when using radios from Freewave Technologies ensures that the radio system will operate reliably year-round under a variaety of conditions. Other radios may require a greater fade margin.

Ultimately, FADE MARGIN is the "bottom line", but remember that the calculated fade margin depends on all of the information supplied (antennas, cables, radios, etc.).

## Elevation Views

Elevation views show a cross section of a radio path which can help explain the results in the path study reports. The cross section shows the straight signal path, the Fresnel zone, and the obsticles that will be encountered based on the digital topological mapping data and GPS coordinates.

An elevation view for the radio path report that we've been working with is pictured here:




Note that the example path that we've been looking at is not really "line of site" because of a hill in the way. Ideally, the blue line that shows the Fresnel zone should be above the terrain, but because of the hill, there is significant reduction of available fade margin due to "diffraction loss" ("running into the hill"). Still, even with this obstacle, the computer analysis of this path shows that it will work reliably with the radios, antennas and cables described in the study.

## So what do I do with a bad path?

Generally, a low fade margin can be improved by elevating an antenna, using a better quality (lower loss) antenna cable and/or changing antennas. If the changes don't solve the problem, then you may need to look at using another site as a repeater. Some radios, such as the Freewave radios modeled in this study, have a built-in repeater function so that an existing site with an RTU can also serve as a repeater station without any additional hardware (or cost). Furthermore, ICL RTUs and Controllers have a Store-and-Forward messaging capability that can help to solve coverage problems, at the expense of network performance (speed).

## Summary

Regardless of whether your study comes out "clean" or with problems, a GPS Radio Path Survey provides "peace of mind" so that you'll have a good idea of how your radio system will perform before purchasing and installing hardware over the countryside. Everyone may not be a radio genius, but the results of the study can be relatively simple to understand and help you make better choices for your wireless system.

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