HOW TO GUIDE: Base Range Optimisation

This document describes the steps you can take to improve the communication range between the mojoRTK base station and console. This is done by explaining the beneficial configurations, pitfalls and trade-offs that exist when setting up radio communications systems that are applicable to the mojoRTK base to console communications.

Description

The most basic (and possibly most common) base to console communications scenario is to have the base station mounted on its tripod and the communications to the console made over flat ground.

There are ways to improve the performance of the base to console communications, some of which may be applicable to your situation and some which are not. There as some things that you can do to improve performance for one situation but make it worse for another.

Some background information will be provided that should help to understand what actions you can take to improve communications performance for the particular situation. Also, base station positions which should be avoided will be described as they can adversely affect the radio performance.

NOTE: This guide does not explain how to resolve issues with a particular customer situation but provides information and concepts to help avoid potential issues and to explain possible ways to improve performance.

Major Points to Achieve Better Radio Performance

The major points here are listed as an initial guide and some are explained in greater detail later.

- **Better performance with clear space between the base and the console**. This seems like a simple concept, however, there is phenomena known as the Fresnel Effect or Fresnel Zones (Fresnel is pronounced *Fray-nell*). This is a complex topic and is further discussed below. It is due to the Fresnel effect that mounting the base antenna on top of a tower helps increase the base communications range.

- **High gain antennas on the base and/or the console can improve communications.** High gain antennas do not provide any extra power when transmitting or receiving. What they do is transmit into and listen from a more directed field resulting in stronger signals to and from that direction. It should be noted that there are cases where higher gain antennas can cause problems with radio performance. Points to note regarding high gain antennas on the base/console radio antennas:
    - You should avoid using a high gain antenna on the vehicle when the vehicle is working on steep terrain (due to the effect shown in Figure 3 later)
    - Also note that in some countries and regions higher gain antennas are prohibited on certain radios or licenses may be required to use them. When using high gain antennas it is important to make sure that you are using the correct antenna for the job. You should consult local communications companies to guide you towards the right antenna.

- **Poor placement of the base station can result in radio reflections which interfere with the direct signal.** There are situations where the base station can be placed in a position with a clear view of the sky for good GPS reception but still be close to a tree, shed, silo, or with a hill behind the base. The problem with having something behind the base station is that the console can receive the direct signal from the base as well as the signal reflected off the object behind the base. This can cause interference patterns in the field which can be very disruptive to the performance of the radio communications.

- **Use of good cables and connectors.** When you are putting the mojoRTK base station antenna at the top of a tower you should use good quality cables so that the signal is not significantly weakened before it reaches the transmitting antenna. Again, you should consult local communications companies to guide you towards the right equipment when extending RF cables. See the 'How To Guide' for fixed base stations with external antenna.

- **Be aware of possible interference from other sources.** Sometimes the communications between the base station and the console may be severely affected by radio interference from an external source or possibly even another mojoRTK base station nearby. The first thing you can try is to change the channel on the base station ***and*** console. You have channels 0 to 3 to choose from with the European 868MHz systems and 0 to 19 on the 900MHz North American and Australian systems. Also note the following:

- Channels 10 to 19 on the 900MHz systems can help avoid interference as those channels actually increase the over-the-air data rate (not the total data, just how fast the bursts of data are sent).
- This helps to avoid interference as the radio requires less transmission time to get the data through potentially avoiding other bursts of transmissions from the interfering devices. However, there is a downside to the higher data rate. The higher data rate can shorten the range when the signal starts to get weak. Its main purpose is to improve reliability when within good range but suffering interference.

- **Basic mojoRTK Base to Console Communications Troubleshooting.** See the points below on general troubleshooting with the mojoRTK base communications:
  - Check that the antennas are vertical and not folded over as the standard mojoRTK antennas can fold down to prevent breakage.
  - The 900MHz base stations sold in North America and Australia provide a multi-transmit option. When turned on, the multi-transmit sets the base radio to transmit each section of data up to 3 more times. The base radio in the console is smart enough to ignore any data that it receives more than once, however, the multi-transmit increases the chance that the console does actually receive the data at least once. To turn multi-transmit on or off you need to go to **Settings→Mulit-Transmit** in the base station menu and choose either Off, 1, 2, or 3. ***NOTE:***
    - ***When you turn multi-transmit on, the base station will use more power and will drain internal or external batteries faster.***
    - ***If you are using a repeater with the internal base radio you should not be using multi-transmit as they are not compatible.***
  - Some radio installers are used to mounting antennas with a ground plane. This should not be done with the standard mojoRTK base radio antennas or any other dipole antenna (if you are using high gain antennas for the base to console antennas they will most likely be dipoles).
  - The 900MHz radios have different transmit mode when you use channels 10 to 19 (explained above) and may be worth a try to avoid interference.

Clear Space Between Base and Console

This section is mainly about elevating the base station antenna by placing the base antenna at the top of a tower. Try to think of the unobstructed space required between the base antenna and the console antenna as a large ellipsoid shown below in Figure 1. This space is known as a Fresnel Zone and there are many more Fresnel zones which wrap around the first zone, each with a greater radius that the previous zone.

(Visit http://en.wikipedia.org/wiki/Fresnel_zone for a highly technical explanation)

Figure 1 – First Fresnel Zone and its obstruction

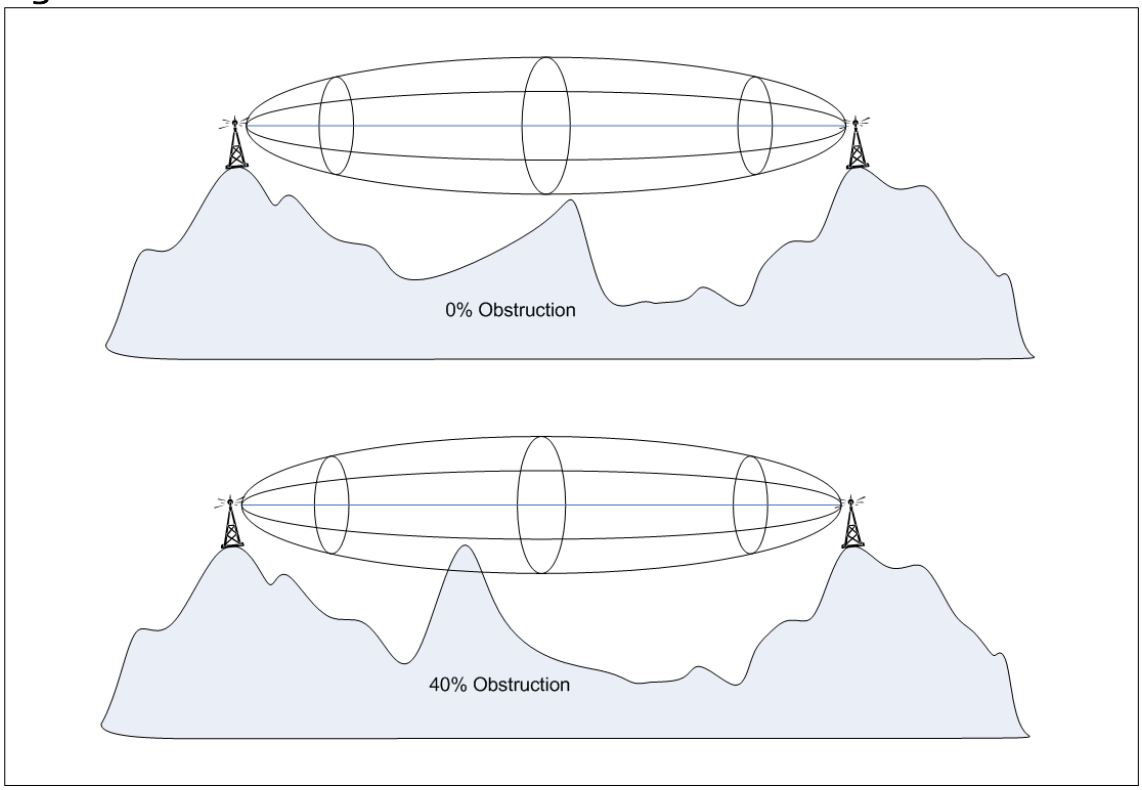
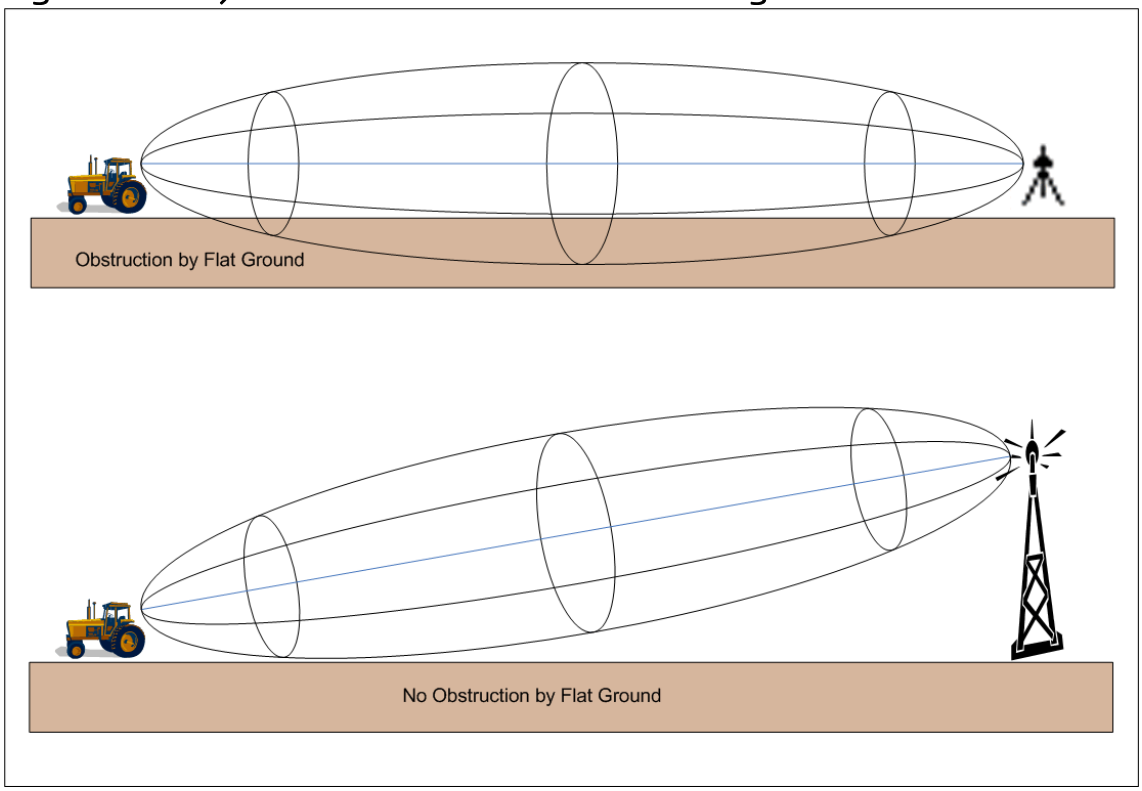


Figure 1 shows two radio towers communicating with each other in two situations. The first situation shows no obstruction of the first Fresnel zone and the second shows some obstruction of the first zone.

Some obstruction of the Fresnel zones can often be tolerated, and as a rule of thumb the maximum obstruction allowable is 40%, but the recommended obstruction is 20% or less.

Figure 2 shows two scenarios for using the mojoRTK base station and console over flat terrain. The first scenario shows the base station set up on the standard tripod. The second shows the base station antenna at the top of a tower for increased antenna height.

Figure 2 – mojoRTK base radio antenna on the ground and elevated



Note: *it is possible to have too much clearance as the radio reflections in the second Fresnel zone interfere with each other in a way which reduces the signal at the receiver. However, when setting up the base radio on a tower it is unlikely that you will get the base antenna high enough to suffer this problem.*

Table 1 shows a list of antenna heights for 40% and 0% obstructions of the first Fresnel zone over different distances between the mojoRTK base station and the console.

It is likely that you won't have a choice as to how high you can mount your base antenna on an existing tower. Use the table below to work out if your antenna height will be below the height for 40% obstruction or above the 0% obstruction height. It would be better to be above the 0% height than below the 40% height but going above the 0% height will introduce more of the disruptive reflections off the ground. This may be somewhat complicated by the fact that you have to work these numbers out over a range of distances and further complicated again because this table is for flat terrain only.

In any case, Table 1 has been provided help make informed decisions and for problem diagnosis.

Table 1 – base antenna heights for 40% and 0% obstruction of the first Fresnel zone over flat ground.

Metric (868MHz and 900MHz)

Distance (km)	40% Obstruction Antenna Height (m)	0% Obstruction Antenna Height (m)
2	16	26
4	22	36
6	27	41
8	33	54
10	38	61

US Standard/Imperial Units (868MHz and 900MHz)

Distance (miles)	40% Obstruction Antenna Height (feet)	0% Obstruction Antenna Height (feet)
1	44	72
2	63	105
3	80	134
4	94	154
5	108	176
6	119	193

NOTE: the calculations in the table were made using an online Fresnel Zone calculator and the antenna heights listed are:

0% Obstruction Antenna Height *= twice the sum of the 1st Fresnel Zone radius and the midpoint ground elevation due to Earth curvature*

40% Obstruction Antenna Height *= twice the sum of the 40% Obstruction Radius and the midpoint ground elevation due to Earth curvature*

You should also think about obstructions that you may get when trying to receive the signal past objects like trees, sheds, silos and so on. Think of these elliptical zones from a top down view as well. Just because you have direct line of sight to the base station from the vehicle looking past an object doesn't mean that you have unobstructed base communications.

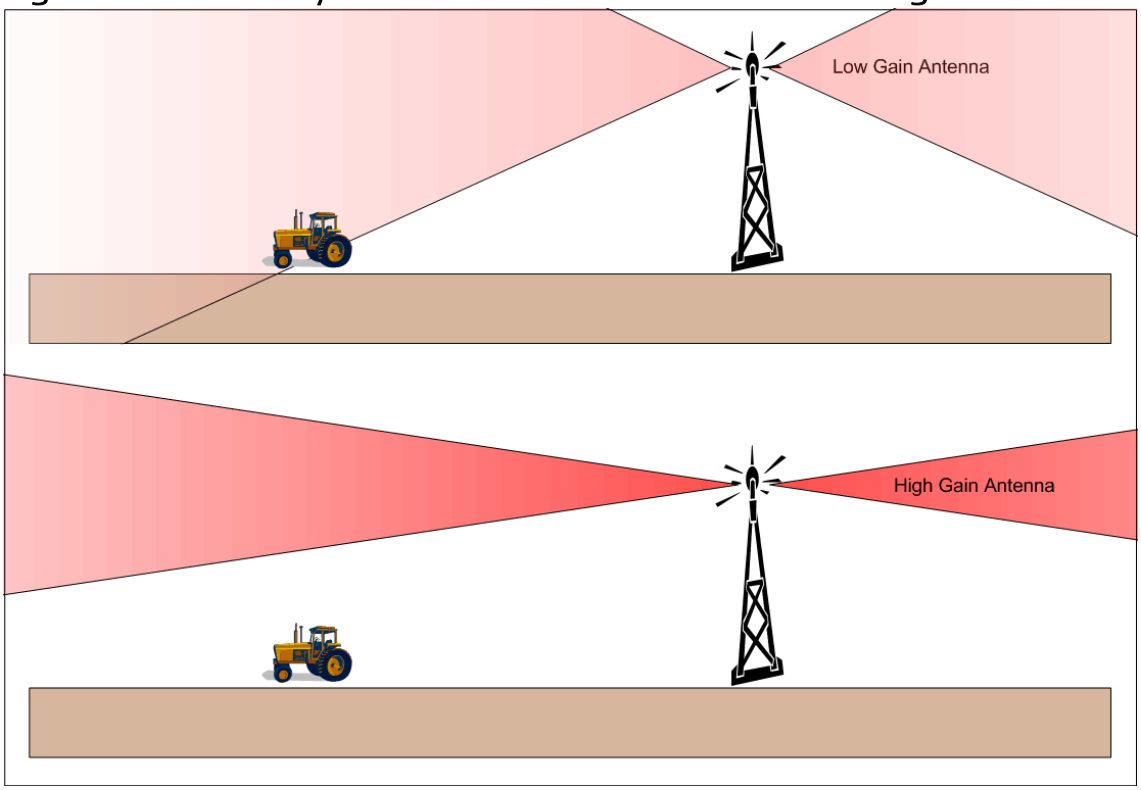
High Gain Antennas

The first thing to note about antennas with higher gain is that they do not produce higher transmit powers, instead they transmit the same power into a more directed field. However, when receiving, high gain antennas do produce more power when the signal is received from its higher gain direction, and lower power when receiving signals from other directions.

Figure 3 shows the basic concept of the difference between antenna gain and antenna directivity. In the diagram, the darker the signal the stronger it is. The low gain antenna spreads the transmitted signal over a greater area and is therefore weaker than the signal from the high gain antenna which transmits the same signal into a smaller area.

You can often obtain the gain pattern of an antenna from the manufacturer or the supplier. The gain patter specification provides a plot of gain versus direction. These plots can be difficult to read but generally provide a general guide as to which directions they don't work well at.

Figure 3 – Directivity of antennas with different antenna gains



NOTE: *although the high gain antenna pushes a stronger signal further out it may cause problems when trying to receive the signal when you are too close to the antenna and it is mounted high up a tower. Also note that the diagram may exaggerate the reduction in transmission area and was drawn only to explain the concept.*

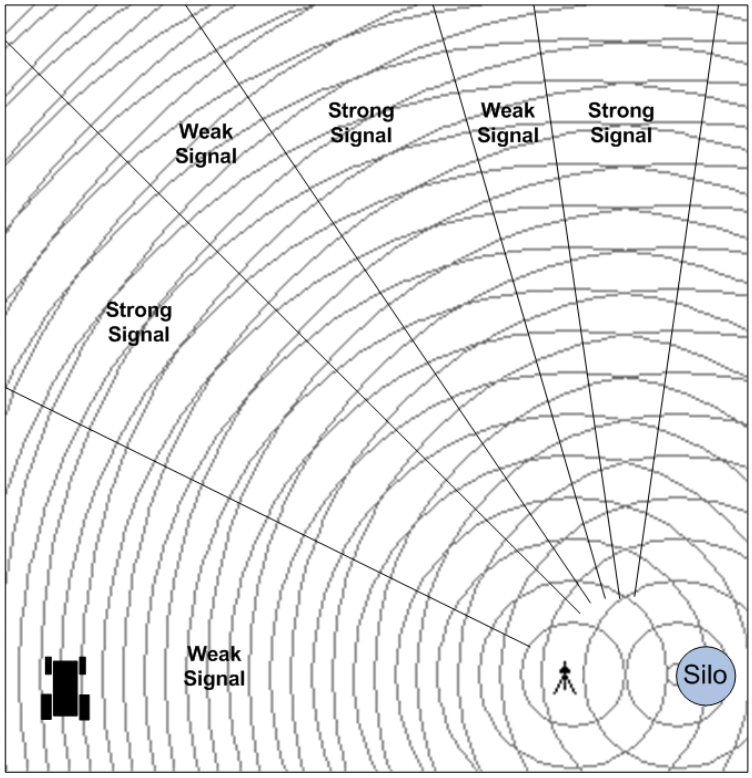
Select the Right Location for the Base Station

One problem that you may encounter with the base radio is interference when the signal is reflected off an object close to the base station. This can be very difficult to measure or diagnose as the cause of any communications problems but as long as you are aware of the issue you can take action to avoid such interference.

Objects that may cause these reflected signals include silos, sheds, or trees. Even a hill close behind the base station can cause reflections if the base station is setup near the top of a hill but not quite at the top.

For the purpose of understanding the effects of the reflected signals Figure 4 shows an extremely simplified interference pattern due the reflections from an object close to the base station. This diagram is drawn as though there are two signal sources, the first is the original signal from the base station and the second is the reflected signal off the silo. The diagram also loosely defines areas of weak signal and strong signal due to the interference, however, note that the diagram doesn't show the signals getting weaker as you get further away from the base and the silo. Also, the reflected signal off the silo would be weaker than the original from the base.

Figure 4 – Basic Interference Pattern due to reflections from an object near the base



When the original signal and reflected signal reach a location in phase with each other they combine in a way that strengthens the signal. However, when original and reflected signals reach a location out of phase they combine to produce a weak signal and theoretically can cancel each other out completely to produce no signal.

It is important to understand that reflected signals don't always cause the desired signal to be weakened. If it appears as though the signal is good in some patches and very poor in others when there is no significant difference in distance from the base you may be experiencing the effects of reflection interference, possibly even an interference pattern from another source such as a mobile/cell tower.