Safely and consistently achieving the desired range is, understandably, very important for any drone pilot.

This article serves as a practical and plain-English guide to the relevant basics of RF theory, antenna selection and design, helping you understand how to safely achieve your desired range for your Inspire, Mavic or Phantom.

As a bit of a sneak preview I’ll start with three interesting facts:

1. Did you know that the 2.4GHz frequency is 2.5 times better than 5.8GHz in terms of maximum theoretical range?
2. Did you know that an expensive 8db antenna may give you much less range than the stock antennas, depending on your circumstances?
3. Did you know that just changing your control’s antenna can give you a range of up to 33km?

**Some initial notes**

The entirety of this info has been taken from The Beginner’s Guide to FPV and tweaked for this article. So, for the proper thing check out the Guide.

RF theory is complex. For the purpose of providing a useful, concise and practical guide I’ve simplified some concepts and have been a bit liberal with some terminology. It is all well intended.

Inspire, Mavic, Phantom and other DJI drones using Lightbridge employ bi-directional digital communications between the control and the drone. As such control and drone are both transmitters and receivers at the same time.

**What factors affect range (and hence, how to maximize it!)**

When considering maximum range of your setup, the following main factors will determine what you can achieve:

1. The positioning of the control and the drone, including obstacles in the space between them
2. The type of antenna on the control and the type of antenna on the drone
3. The power of the transmitter on the control and the power of the transmitter on the drone
4. The frequency being used
5. Reflective obstacles behind and around the control and drone
6. Interference from other RF sources
7. The relative orientation of the control and the drone
8. The positioning of the antenna within the drone

As you can see the list is quite long and just includes the key factors. There’s a longlist that includes factors such as air moisture content but I’ll leave these out for now!

Now, lets take each of these in turn…

1. **The positioning of the control and the drone**

It is quite obvious that if there are obstacles in the line of sight between the control and the drone then the signal will deteriorate.

However, that’s only half the truth as even obstacles that are not directly in the line of sight have a significant impact. More specifically, any obstacles in the “Frensel zone”, will impact range.

In simple terms, the Frensel zone is an area the shape of a rugby ball between the transmitter and the receiver. To achieve the best link this area should be free of obstacles. The following diagram illustrates this point.



So, if your signal is getting weak, many times all you need to do is fly a bit higher and clear your Fresnel zone.

1. **The relative orientation of the control and the drone**

This point is applicable to linear polarized antennas which, at the time of writing, comprise all of the antennas available for the Phantom, Mavic and Inspire.

When using such linear polarized antennas, it is important to keep the receiving and the transmitting antennas in the same orientation, for example, both vertical (pointing up).

However, this may not always be possible. For example when the drone banks this may introduce a 45 degree orientation mismatch which will result in a significant signal degradation.

1. **The type of antenna on the control and the type of antenna on the drone**

This is where it gets interesting… In this section we’ll discuss the radiation pattern and gain of antennas.

Each antenna has a specific radiation pattern. Some antennas will broadcast (or receive) equally in all directions (in which case the radiation pattern is a sphere centred around the antenna) while other, highly directional, antennas will only transmit (or receive) in a narrow cone in front of them. A good example of a directional antenna is the typical TV aerial which needs to be pointed in the right direction to work.

The more directional an antenna is the higher its gain. A good analogy is comparing a household lightbulb (low directionality, short range) to a flashlight (high directionality, long range). Gain is measured in dB, with unidirectional antennas having typically 1-3dB and directional having usually 8-15dB.

The impact of gain is huge. For example, other things being equal, a 2dB antenna on 2.4GHz will give you a range of 6km while a 16dB Yagi antenna will increase this range to 33km.

The standard DJI antennas are low gain, meaning they receive broadly equally well in all directions.

The choice of radiation pattern depends on your style of flying (e.g. a long range flight in the same direction or a shorter range flight around the pilot) and your equipment (e.g. an antenna tracker will enable a directional antenna to always point to the plane).

In addition to directionality, examining the radiation patterns will reveal other considerations the pilot will need to take into account. For example, even unidirectional antennas typically have a doughnut shaped pattern, with a low-sensitivity area right above and below them. As such it is common for the video signal to be weak when flying directly over the pilot.

The following diagram provides an illustration of the differences between omni and directional antennas as well as two representative actual radiation patterns (“vertical”, as seen from the side and “horizontal”, as seen from above)



*Illustration of antenna directionality (gain)*

So, to summarize:

1. High gain antennas (with gain >2db) will provide great range when flying directly infront of it but really terrible range when flying behind it
2. Even the stock antennas have a weak spot right above the pilot, so be aware when flying directly overhead
3. **The power of the transmitter on the control and the power of the transmitter on the drone**

Obviously, the higher the power the greater the range. But devil’s in the detail…

Range is proportional to the **square** of the power. This means that doubling your power will only increase your range by around 40%.

So, don’t get too excited by all those power amplifiers out there.

1. **The frequency being used**

This is another critical factor as frequency plays a massive role on range.

The lower the frequency, the longer the range. As such, if you choose the frequency on your setup be aware that unless you’re in an area of significant interference in the 2.4GHz band, then 5.8GHz will not be your best choice.

To bring this to life, other things being equal 5.8GHz provides roughly half the range of 2.4GHz.

1. **Interference from other RF sources**

When thinking of interference you need to consider three things:

1. Its only interference if its in your frequency (there are also some effects on half or double frequencies but that’s not that important)
2. Its only interference if it is within your radiation pattern. I.e. if using a high gain antenna, it doesn’t matter as much if there’s interference behind you
3. Its only a problem if interference is higher than your transmitter’s power (given distance and all other factors)

A practical illustration:

* Lets say you’re using a high gain antenna (a directional antenna)
* Lets say you lift off from a nice grassy area outside of town.
* You gain altitude and start flying towards the town with no issues
* You start descending when suddenly you lose all signal
* The reason here may well be that as the drone is getting closer to the town’s houses, a strong source of interference on 2.4GHz (lets say a Wifi router) has suddenly appeared within your antenna’s radiation pattern

1. **The positioning of the antenna within the drone**

Most pilots have experienced signal issues when at range and rotating their drone. A likely reason is that the drone’s antenna’s radiation pattern is blocked by some of the drone’s circuitry.

Its useful to know that one of the worse blockers of RF are LiPo batteries, which is why it is advisable for antennas to be located under the drone and not within its shell.

1. **Reflective obstacles behind and around the control and drone**

Finally, its worth being conscious of where you setup your ground station and in particular whether you’ll be subject to multipath interference.

Multipath is an issue that occurs when the signal reaches the receiver from multiple paths or directions. This would typically happen when the signal bounces off obstacles.

So, try to avoid setting up close to large obstacles, even if these are behind you and your line of sight to the drone is clear.