1 | Fresnel Zones

Fresnel zone [ZyTrax, Inc, 2016] [4Gon Solutions, 2016] calculations gives a mean to calculate on how to avoid the strongest radio signals to impact the direct line signal caused by reflections of obstacles, which will make out of phase signals which will be added with the direct line signal, which can cause power loss. There are an infinite amount of Fresnel zones, and will all impact the direct line signal.

In terms of a radio signal travelling from a transmitter to a receiver it can travel through different paths. It can travel directly without any reflection. Or it could reflect of the ground and thereby carry on to the receiver, or it could be reflected by a hill, and carry on to the receiver. These reflections cause a signal loss from the transmitter to the receiver. The receiver does not differentiate between the reflected and the direct line signals, and therefore it will consider both the reflected and the direct line signal as the intended signal.

If these signals reflect of an obstacle and are out of phase with the direct line signals, they may end up having phase cancellation effect which could end up minimizing the power of the signals. For example two identical radio signals out of phase will cancel each other out and therefore no signal will be received, by the receiver. So therefore when calculating Fresnel zones it must be taken into consideration which out of phase signals from reflections have the most effect on the direct line signal, and make sure that it does not lose a lot of power.

There are an infinite amount of Fresnel zones, but the most important Fresnel zone is the first one. This is due to that the strongest signals are the ones that are closets to the direct line signal and they always lie in the first Fresnel Zone. Which also means that the second, third and so on Fresnel zones are further and further from the Direct signal and they will have a lesser impact. This can be seen on the following Figure, which is illustrated with 2 Fresnel zones, Fresnel zone 1 and 2:

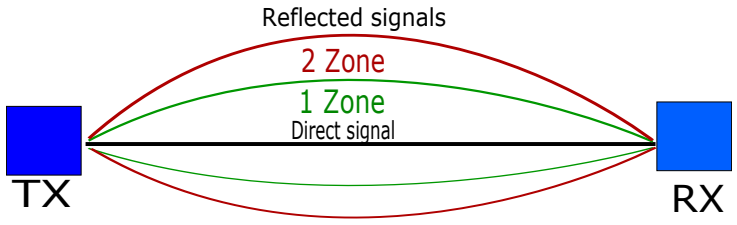

Figure 1.1: Illustration of the First and Second Fresnel zone, along with the Direct signal travelling from the Transmitter TX to the Receiver RX

As it can be seen the first Fresnel zone is closets to the direct signal and will have the strongest cancelling effect, if not taken into consideration. And the least amount of delay is in the reflected signal of the first Fresnel zone as it travels least from the transmitter

to the receiver. And it will create signals that are 0°-90° out of phase, which is the least out of phase the signals can arrive. The less the reflected signal is out of phase, the less it will affect the direct line signal, as the receiver treats both as one. In terms of the second Fresnel zone, it can create problems, in zone two they will be 90° to 270° out of phase. The phase cancelling effect in even numbered Fresnel zones are bad while odd numbered zones are good, as they can have a positive effect, as they may add to the power. A rule of thumb in terms of the first Fresnel zone is that 60% *of the first Fresnel zone must be cleared of any obstacles*, as the strongest signals are in Fresnel zone 1.

Fresnel zone 1

As mentioned 60% of the first Fresnel zone must be cleared of objects, an illustration of this can be seen on the following Figure:

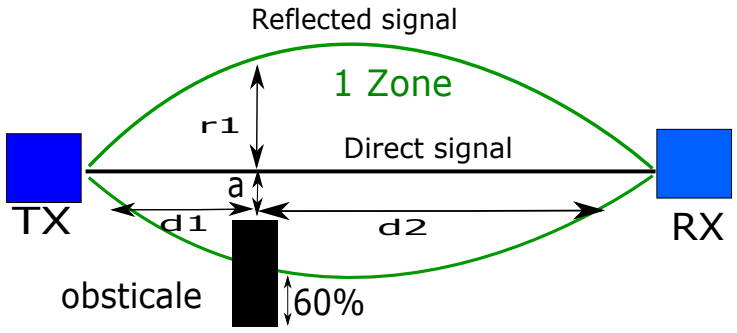

Figure 1.2: Illustration of the First Fresnel zone cleared 60%, with an building representing the obstacle

The obstacle on the Figure above could illustrate a building where d_1 is the distance from the transmitter TX to the building while d_2 is the distance from the receiver RX to the building. While a is the center line of sight, which means that there is a obstacle free direct view to the receiver, for the signal to travel. So the building must not be closer than 60% of the measured $r1$ which is the radius of the first Fresnel zone from the center line of sight a, to fulfil the requirement of 60% clearance, in the first Fresnel zone. Which in other words means that there must be 60% line of sight, according to the radius of the first Fresnel zone, which represents the impact of the reflected signal ,to travel with the direct signal.

Fresnel Zone calculations

The general equation for calculating the Fresnel zone radius at any point a in between the endpoints is given as:

$$F_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}} \tag{1.1}$$

Where:

F_n	The n^{th} Fresnel Zone radius	[m]
d_1	The distance of a from TX	[m]
d_2	The distance of a from RX	[m]
λ	The wavelength of the signal	[m]

It is useful to know the maximum radius of the first Fresnel zone. With the maximum radius of the first Fresnel zone and the obstacle height, the maximum obstacle height can be calculated, with respect to 60% clearance.

While we know that λ is the wave length given by the following Equation:

$$\lambda = \frac{c}{f} \tag{1.2}$$

Where:

c	The speed of light in a vacuum	$[3{\cdot}10^8 ms^{-1}]$
f	Signal frequency	$[Hz]$

And the by inserting λ, and where $n = 1$ as it is the first Fresnel zone. And d_1 and d_2 can be classified as the total distance D. The when inserting there parameters in the general equation for calculating the maximum Fresnel zone radius, we get the following Equation:

$$r = 8.67 \cdot \sqrt{\frac{D}{f}} \tag{1.3}$$

Where:

D	Total distance	[m]
f	Signal frequency	[Hz]

As an example to calculate the maximum radius of the first Fresnel zone of two antennas operating 5.5 GHz, with a distance D of 500m. The 60% clear Fresnel zone maximum radius r is given as:

$$r = 8.67 \cdot \sqrt{\frac{0.60 \cdot 0.50}{5.5}} = 2.02m \tag{1.4}$$

The by subtracting the antenna height form r, the maximum height with respect to the

60% clearance, can be calculated. So if the the antenna height is 10m, then by subtracting 10m-2.02m we get 7.89 m, which is the maximum obstacle height.

Bibliography

4Gon Solutions (2016). Fresnel Zones. http://www.4gon.co.uk/solutions/technical_fresnel_zones.php.

ZyTrax, Inc (2016). Tech Stuff - Wireless - Fresnel Zones and their Effect. http://www.zytrax.com/tech/wireless/fresnel.htm.