

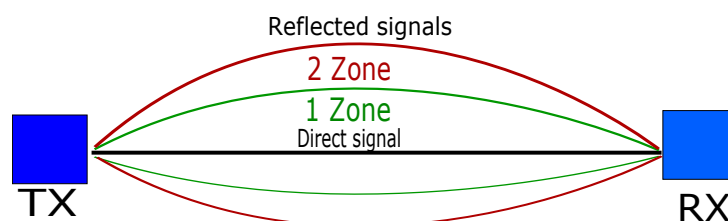
# 1 | Fresnel Zones

Fresnel zone [ZyTrax, 2016] [Solutions, 2016] calculations gives a mean to calculate on how to avoid the interference from the strongest radio signals that are not direct line signals. This can be caused by reflections of obstacles, these reflected signals will have a different phase and when added with the direct line signal, may cause power loss. There are an infinite amount of Fresnel zones, and all will impact the direct line signal.

In terms of a radio signal travelling from a transmitter to a receiver it can travel along 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 can 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 [Solutions, 2016]. It is important to notice that there will be a phase shift of  $180^\circ$ , if the wave is linearly polarized and hits a surface that is parallel to the waves polarization.

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 obstacles in these will have a lesser impact [Seybold, 2005]. This can be seen on the following Figure, which is illustrated with 2 Fresnel zones, Fresnel zone 1 and 2:



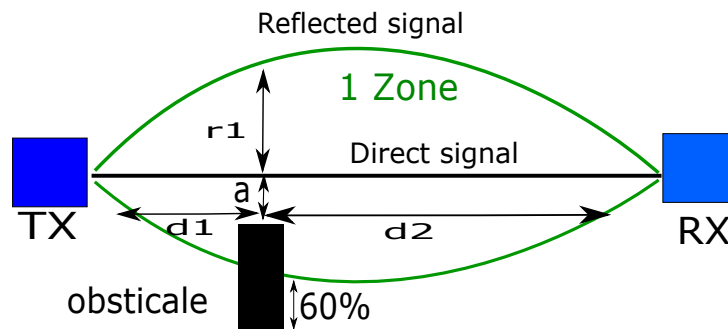
**Figure 1.1:** Illustration of the First and Second Fresnel zone, along with the Direct signal travelling from the Transmitter TX to the Receiver RX

As it can be seen the first Fresnel zone is closest to the direct signal and will have the

strongest cancelling effect, if not taken into consideration. It has the least amount of delay in the reflected signal of the first Fresnel zone as it travels least from the transmitter to the receiver. Inside the first Fresnel zone phase delay due to increase in path distance of the reflected wave are  $0^\circ$ - $90^\circ$ , when remembering the phase change done by the reflection itself that means the signal is  $180^\circ$ - $270^\circ$  out of phase in total. When the reflected signal then interferes with the direct signal destructive interference occur. In terms of the second Fresnel zone, it creates longer phase delay, in total between  $270^\circ$  to  $450^\circ$  out of phase. This become constructive interference. The phase cancelling effect in even numbered Fresnel zones are good while odd numbered zones are bad. 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 this reduces the destructive interference significantly [Seybold, 2005][Solutions, 2016].

### 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. The radius of the first Fresnel zone is  $r_1$ . The distance from the direct signal to the obstacle is  $a$ . With this in mind the rule of thumb states that  $a > 0.6 \cdot r_1$ .

### Fresnel Zone calculations

The general equation for calculating the Fresnel zone radius at any point  $a$  in between the endpoints is given as [Seybold, 2005]:

$$F_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}} \quad (1.1)$$

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]
$\lambda$	The wavelength of the signal	[m]

A conservative calculation of the 60% rule of thumb is to use the maximum radius of the first Fresnel zone to calculate maximum obstacle heights.

The wavelength  $\lambda$  can be expressed as:

$$\lambda = \frac{c}{f} \quad (1.2)$$

Where:

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

The maximum radius is found at the point where  $d_1 = d_2$ . Then by using this as well as setting  $n = 1$  as it is the first Fresnel zone. An expression for the maximum radius can be found and if Equation 1.2 is inserted into Equation 1.1 that yields:

$$r = 8.67 \cdot \sqrt{\frac{D}{f}} \quad (1.3)$$

Where:

$D$	Total distance = $d_1 + d_2$	[km]
$f$	Signal frequency	[GHz]

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

$$a = 0.60 \cdot 8.67 \cdot \sqrt{\frac{0.50}{5.5}} = 1.57m \quad (1.4)$$

Then by subtracting the antenna height from  $a$ , the maximum obstacle height with respect to the 60% clearance can be calculated. So if the the antenna height is 10m, then by subtracting 10m-1.57m we get 8.43 m, which is the maximum obstacle height.



# Bibliography

Seybold, J. S. (2005). *Introduction for RF Propagation*. JOHN WILEY and SONS, INC.

Solutions, G. (2016). Fresnel Zones. [http://www.4gon.co.uk/solutions/technical\\_fresnel\\_zones.php](http://www.4gon.co.uk/solutions/technical_fresnel_zones.php).

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