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Radio connection distance and RF setup
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RF link distance

The link distance depends on many factors, such as power of the transmitter, antenna gain and height, quality of the receiver, frequency used and on the topography of the terrain. You will also achieve longer distances transmitting over water than land, but even then the distance varies depending on whether the water is warm or cold! Thus no fixed answer to this question exist.

Typical "rule of thumb" is that it is needed to raise the antennas as many meters from the ground level as is intention to reach distance in kilometers. The radio frequency bends over the horizon a bit, but all obstacles that comes to the zeppelin shaped Fresnel zone between the antennas effect to the RF link maximum range. Thus the typical ranges with around 400 MHz frequency range with 1 W transmitter power are up to ~30 kilometers and up to ~80 kilometers with 10 W transmitter power. See sample picture of a RF link functional factors at the end of this document.

The links can be extended by using repeater radio stations. SATEL radios can be configured as a master radio station, remote and repeater at the same time, remote station or standalone repeater, no specified radio models for different stations required.

SATEL provides network design services for SATEL users by simulating the planned network radio links (link to link or coverage area) with a software tool. With planned radio station GPS coordinates, the required antenna heights, antenna RF cable type can be evaluated for the system network.

Please contact SATEL Network Design Center for more information: NDC@SATEL.com

Signal propagation

In a typical radio link the static radio stations can be built with higher antenna systems than the mobile radio stations, thus balancing the missing antenna heights at the mobile/remote stations.

It is not required to have clear line of sight between the antennas, but recommendation is to have at least 60% of the Fresnel zone available for the signal. Radio connectivity can be reached also in topography where there is no visible line of sight between the antennas, such as urban areas. See sample calculation of the Fresnel zone at the end of this document.

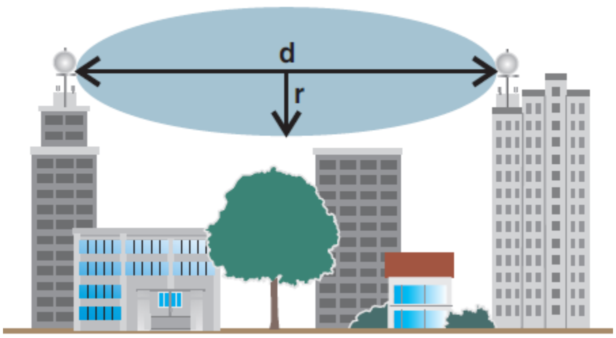

Figure 1, Fresnel zone between antennas

As the RF signal propagates not only directly, but also reflecting from the surfaces, bends around obstacles and also diffracts, some of the phenomena cause signal loss, some also help the signal to get to the destination. Good example area is urban environment, where the building walls help to create radio links of several kilometers with the reflections without direct line of sight between the antennas.

By using directional antennas in the system, the antenna reflection has gain towards certain direction. This way longer links can be created and also possible disturbing signals can be blocked out from the network. Omnidirectional antennas have to be used in case the station is mobile and no static direction can be defined, thus the radio link range can be limited accordingly.

Transmissions power effect to the distance

It is a common misconception that in order to achieve twice the distance in a radio link, you can simply double the power. The reality is that in order to double the distance, 4 times the TX power is needed. This rule comes from a simple geometric formula: the propagation of radio waves expands in the shape of a sphere, and the surface of a sphere (and thus power density) changes proportionally to the square of the radius (in this case the radius = distance).

To put it simply, if with a 1 W transmitter you can reach only 10 kilometers, in order to reach 20 kilometers, you will need a 4 W transmitter.

A very useful way to calculate radio links parameters is using dB's. In this case, mathematics shows that doubling the power is the equivalent to increasing the power by 3 dB. It can also be demonstrated that doubling the distance is the equivalent of an increase by 6 dB. Seen below is a table of equivalence between Watts and dBm.

1 mWatt = 0 dBm
1 Watt = 30 dBm
2 Watt = 33 dBm
4 Watt = 36 dBm
10 Watt = 40 dBm
20 Watt = 43 dBm
40 Watt = 46 dBm

Antenna installation

Recommendation is to keep at least one meter free space around the antenna, keeping in mind that it is recommended to keep as much as possible free line of sight between the antennas.

Multiple RF systems in same location

Multiple RX stations can be used without limitations in the same area. Limitations apply when there are radio transmitters in the same area.

There are many factors that effect to using multiple RF systems in the same location, most significantly the antenna separation, frequency separation and TX power. A good rule of thumb is to have 5 meters in vertical axis, and/or 50 meters in horizontal axis separation to transmitting RF station. Best way for the antenna separation is to have the antennas separated vertically (vertical polarization antennas), as the horizontal separation has to be approx. 10 times the vertical separation in order to gain the same results. In case the required antenna separation cannot be archived, low cost RF components can be added to the RF setup for communication robustness (RF filters, isolation kits).

Formula for calculating the diameter of the Fresnel zone

$r = 0.5\ x\ \sqrt{\lambda\ x\ d}$
r = Radius of the Fresnel zone
λ = Wavelength
Samples:
2 meters for 150 MHz
0.750 meters for 400 MHz
0.345 meters for 868 MHz
0.125 meters for 2.4 GHz
d = Distance between the antennas (meters)

Sample calculation
Radius of the Fresnel zone for 400 MHz and d = 3000 meters:
$r = 0.5\ x\ \sqrt{0.75\ x\ 3000}$
r = 27.71 m
Result: the radius of the Fresnel zone is 27.71 m at a wavelength of 0.75 m (400 MHz) in a distance of 3000 m between the antennas.

Radio communication system – functional factors

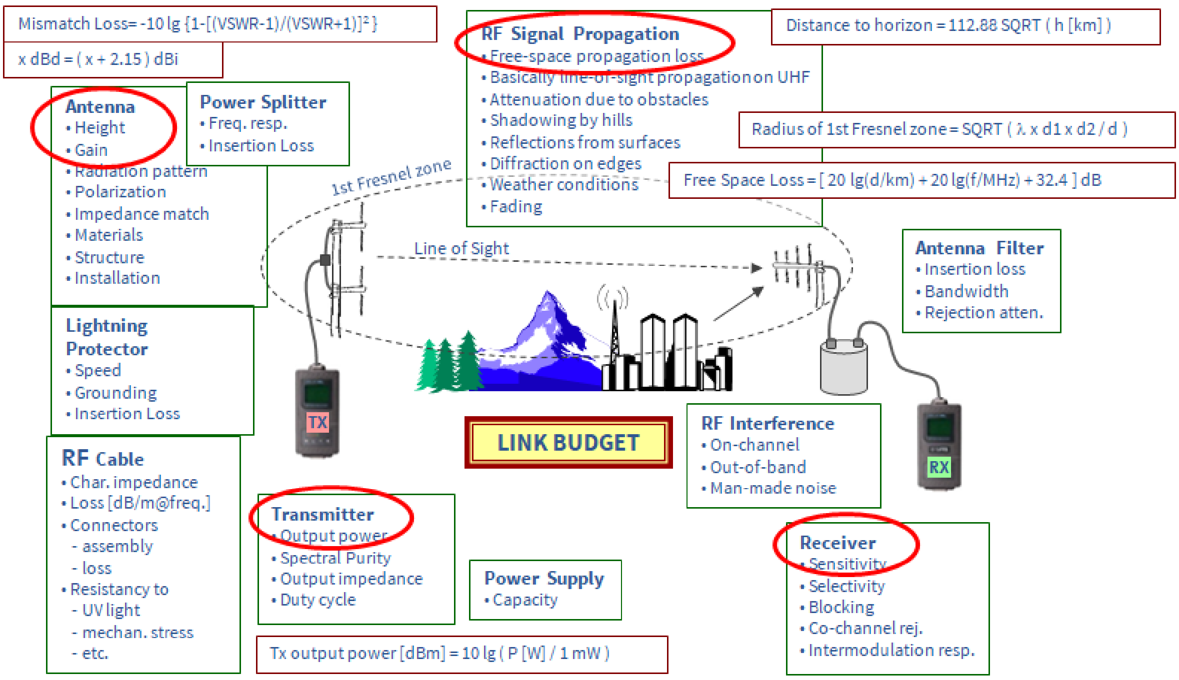

Figure 2, functional factors.