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 high transmitter power levels (10 … 35 W). See sample picture of a RF link functional factors at the end of this document.

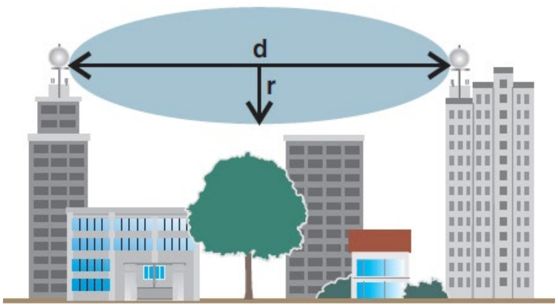
The links can be extended by using repeater radio stations. A SATEL radio can be configured as a master radio station, remote, remote/repeater or standalone repeater, no specific radio models for different stations required.
SATEL provides network design services for SATEL device users by simulating 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, recommended antenna and RF cable types 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 a clear line of sight between the antennas, but the 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 diffracts, some of the phenomena cause signal loss, some also help the signal to get to the destination. A good example area is the 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 of 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 to achieve twice the distance in a radio link, you can simply double the power. The reality is that 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, 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.

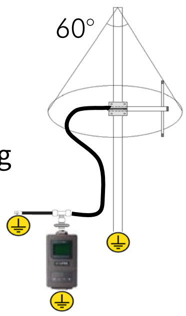
1 mWatt = 0 dBm
1 Watt = 30 dBm
2 Watt = 33 dBm
4 Watt = 36 dBm
10 Watt = 40 dBm
20 Watt = 43 dBm
40 Watt = 46 dBm

Especially with high gain or directional antennas, ERP (Effective Radiated Power) / EIRP (Effective Isotropic Radiated Power) limitations should be taken into consideration.

Installation guidelines

"Rules of thumb" for the field RF installations:

- Antenna needs to be raised at least as many meters from the ground level as is needed to reach in kilometers with the RF signal. This generic rule is good for up to ~12 km
- Antennas do not require visual connection in the RF link, but at least ~60% of the line-of-sight needs to be covered for robust RF connection. For best performance the antenna should clear the surrounding objects as much as possible, antenna can "see" over surrounding trees and objects
- Antennas need to be placed in a position with at least 1 meter of free space around. Nearby objects can affect the antenna radiation pattern. Electrical devices near antenna can also cause interference to the system (lamps, transformers, laptops etc.), which can cause lost data!
- Protect all RF connectors! Any moisture in the connectors will attenuate signal significantly but will also cause corrosion in the connectors
- To reduce the risk of lightning strike damage, use lightning protectors and design grounding for the radio and antenna mast. Install the antenna to bit lower section of the installation pole. See picture on the right, antenna inside "invisible 60°-degree protective cone"



Multiple RF systems in same location

Multiple RX stations can be used without limitations in the same area. Limitations apply when there is a radio transmitter in the same area where a radio receiver is installed. Often the radio stations are transceivers, transmitter/receiver radios.
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. The best way for antenna separation is to have the antennas separated vertically (vertical polarization antennas), as the horizontal separation needs to be approx. 10 times the vertical separation 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).

Radio communication system – functional factors

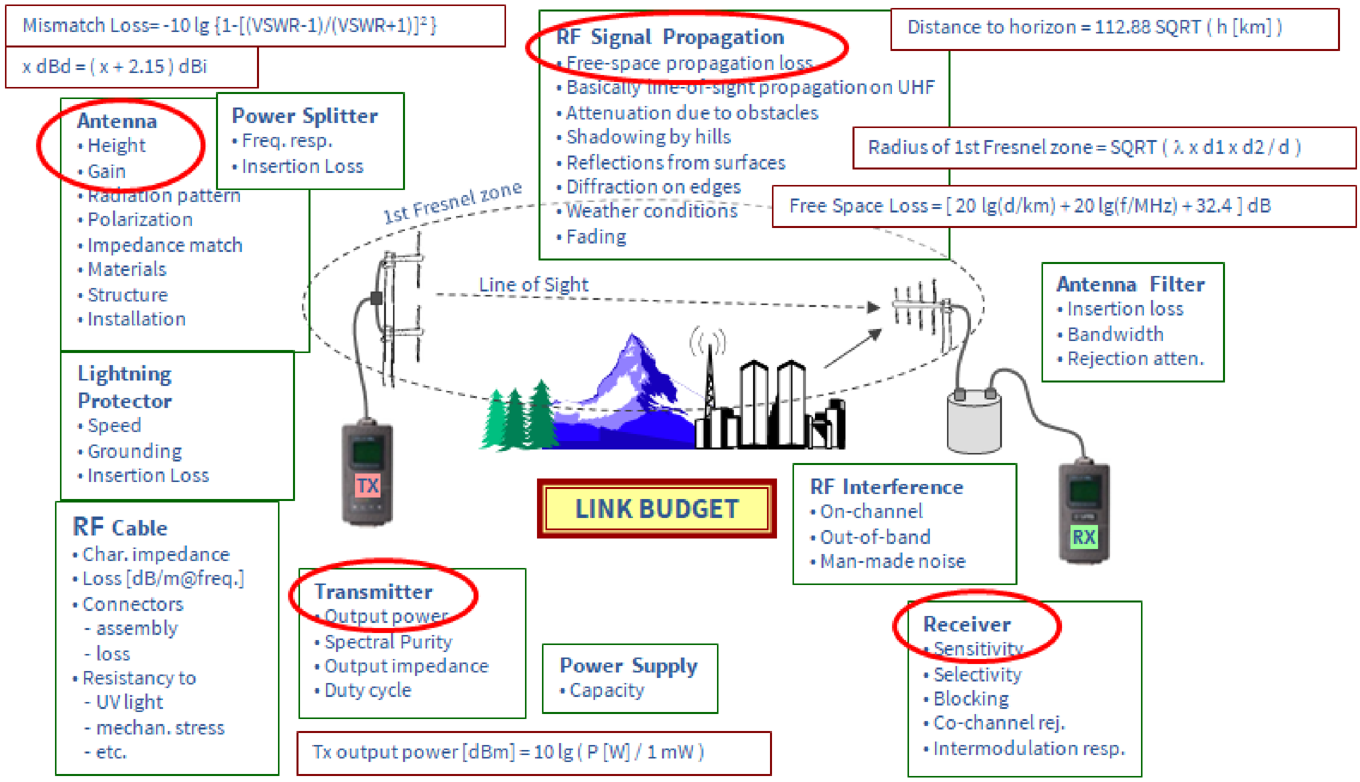


Figure 2, functional factors.

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)

<u>Sample calculation</u>

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 27.71m at a wavelength of 0.75m (400 MHz) in 3000 m distance.