Fresnel zone of Wireless Communication

Visual LOS

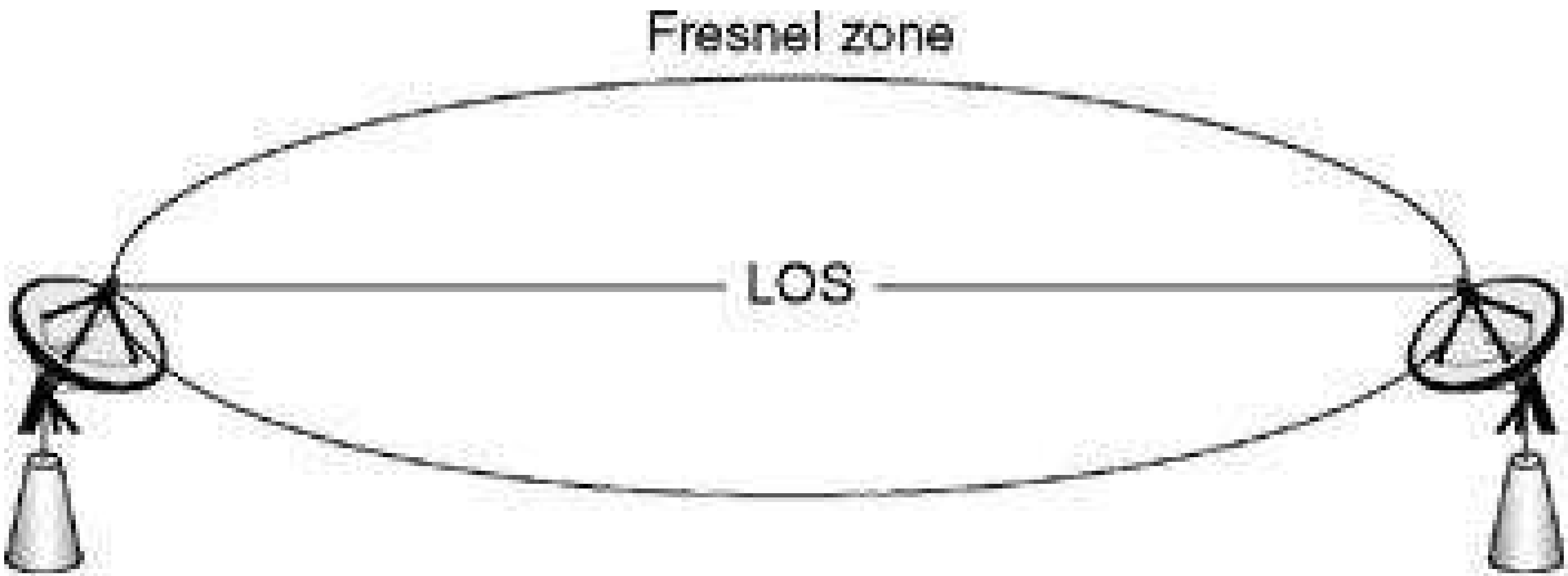
If you stand on top of some tall building, you can see for a very great distance. You may even be able to see for many miles on a very clear day. If you can physically see something, it is said to be in your *visual line of sight (visual LOS)*. This LOS is actually the transmission path of the light waves from the object you are viewing (transmitter) to your eyes (receiver).

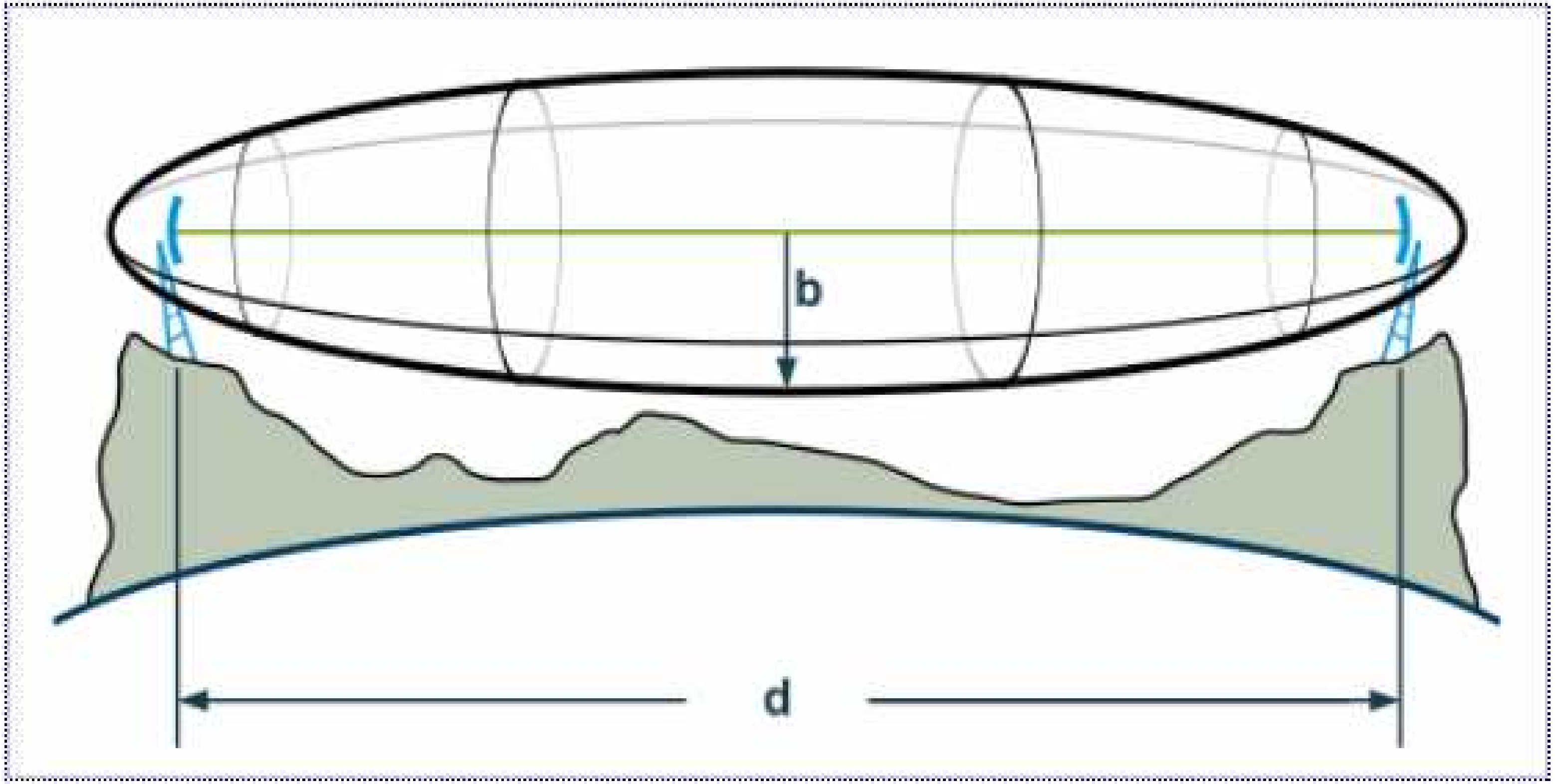
RF LOS

RF LOS is more sensitive than visible LOS to interference near the path between the transmitter and the receiver. You might say that more space is needed for the RF waves to be seen by each end of the connection. This extra space can actually be calculated and has a name: the ***Fresnel zone.***

The Fresnel Zone

- The Fresnel zones (pronounced *frah-nell*), named after the French physicist Augustin-Jean Fresnel, are a theoretically infinite number of ellipsoidal areas around the LOS in an RF link. Many WLAN administrators refer to the Fresnel zone when it is more proper to refer to the first Fresnel zone, according to the science of physics. While it may be the intention of most WLAN administrators to reference the first Fresnel zone when they speak of only the Fresnel zone, it is important that you understand the difference. The first Fresnel zone is the zone with the greatest impact on a WLAN link in most scenarios. The Fresnel zones have been referenced as an ellipsoid-shaped area, an American football-shaped area. Figure 1 shows the intention of this analogy.


Fresnel zone
LOS



Fresnel zone: *d* is the distance between the transmitter and the receiver; *b* is the radius of the Fresnel zone.

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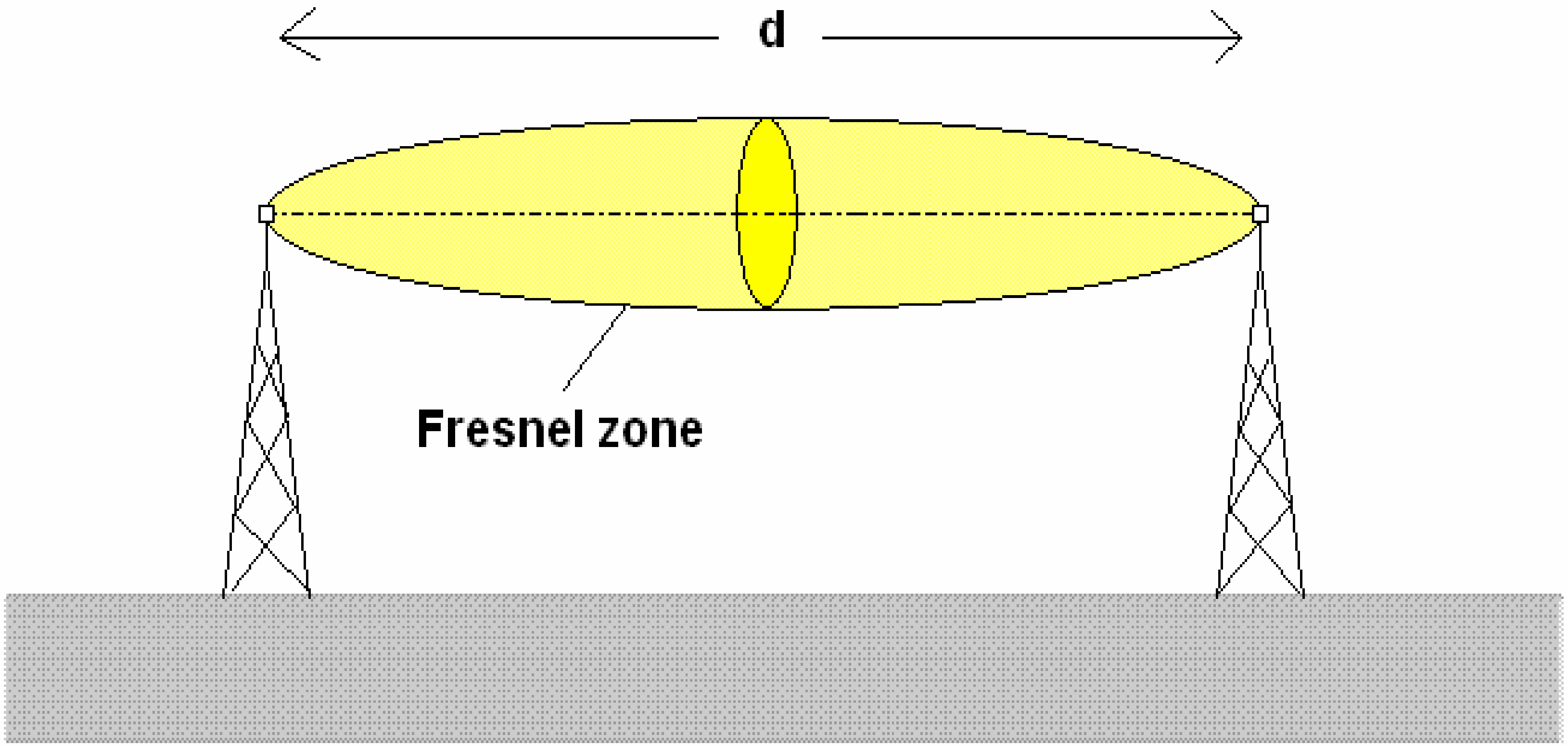

d
Fresnel zone

- In this text, I will call Fresnel zone 1 *1FZ* from this point forward for simplification. Since 1FZ is an area surrounding the LOS and this area cannot be largely blocked and still provide a functional link, it is important that you know how to calculate the size of 1FZ for your links. You'll also need to consider the impact of Earth bulge on the link and 1FZ.

Fresnel Calculations

To calculate the radius of the 1FZ, use the following formula:

$$Radius = \sqrt{72.2 \times (D/(4 \times F))}$$

$$= 72.05 \times \sqrt{\frac{d\ (\text{Miles})}{4f\ (\text{GHz})}} \qquad = 17.32 \times \sqrt{\frac{d\ (\text{Km})}{4f\ (\text{GHz})}}$$

where *D* is the distance of the link in miles and *F* is the frequency used for transmission in GHz and *radius* is reported in feet.

For example, if you are creating a link that will span 1.5 miles and you are using 2.4 GHz radios, the formula would be used as follows:

$$72.2 \times \sqrt{(1.5/(4 \times 2.4))} = 28.54 \text{ feet}$$

- it is important to realize that a blockage of the 1FZ of more than 40 percent can cause the link to become nonfunctional. To calculate the 60 percent radius, so that you can ensure it remains clear, use the following formula:

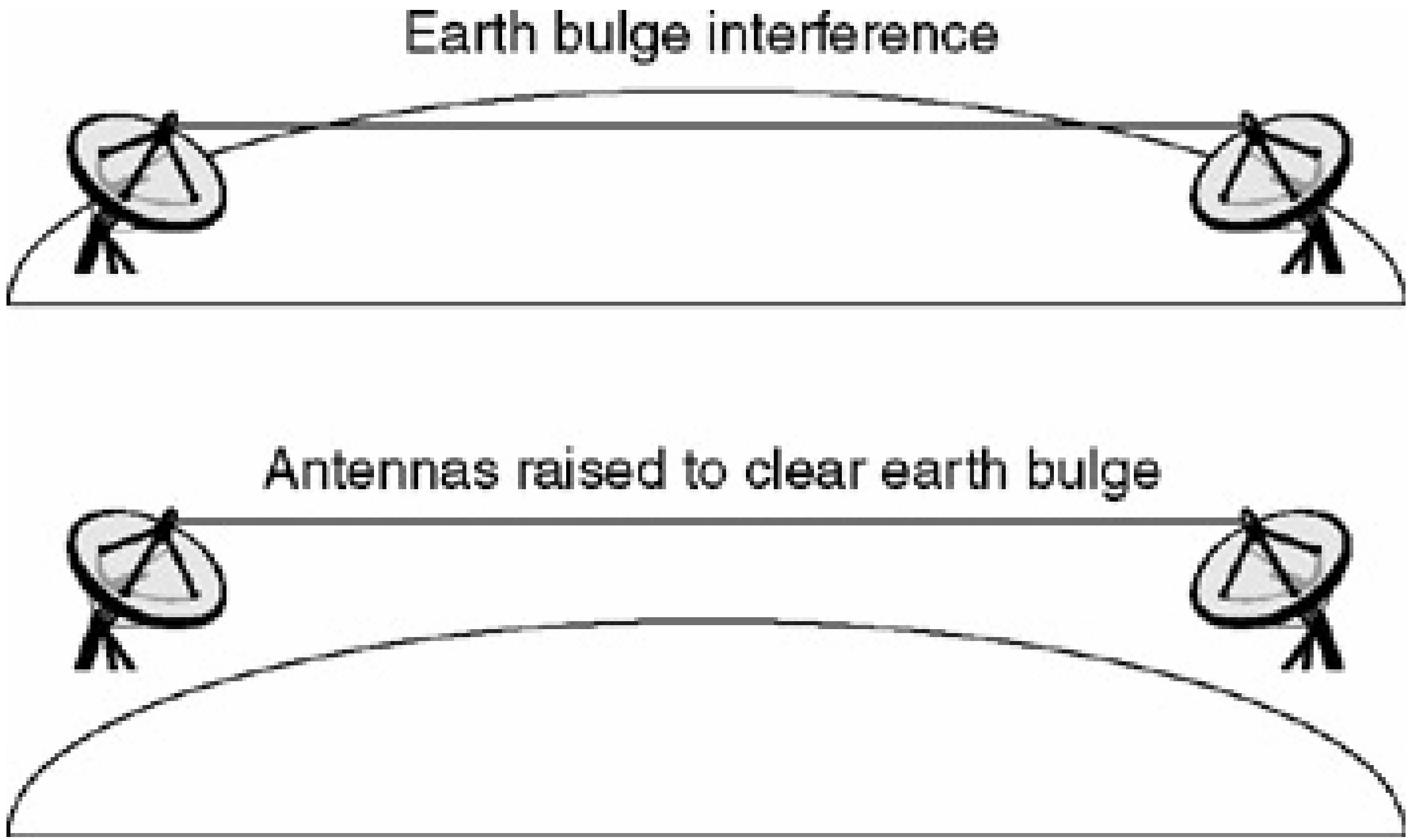
$$Clearance\ radius = 43.3 \times \sqrt{(D/(4 \times F))}$$

where *D* is the distance of the link in miles and *F* is the frequency used for transmission in GHz and *radius* is reported in feet. Using the same example we used to calculate the radius of the entire 1FZ, you will now see that the 60 percent clearance radius is only 17.12 feet.

However, this leaves no room for error or change. For example, trees often grow into the 1FZ and cause greater blockage than they did at the time of link creation. For this reason, some WLAN engineers choose to use a 20 percent blockage or 80 percent clearance guideline, and this is the recommended minimum clearance.

Earth Bulge and the Fresnel Zone

Another factor that should be considered in 1FZ blockage is the Earth itself. As you know, the Earth—it turns out—is round. This means that the farther apart you and I are (or any two objects for that matter), the greater will be the likelihood that the Earth is between us. This is demonstrated in Figure 2.


Earth bulge interference
Antennas raised to clear earth bulge

If you are creating wireless links over distances greater than 7 miles using WLAN technologies, you will need to account for Earth bulge in your antenna-positioning formulas. Earth bulge is a potential problem in outdoor wireless links over greater distances. The formula to calculate the extra height your antennas will need to compensate for Earth bulge is

$$\text{Height} = D^2/8$$

where *height* is the height of Earth bulge in feet and *D* is the distance between antennas in miles. Therefore, if you are creating an 8-mile link, you would process the following formula:

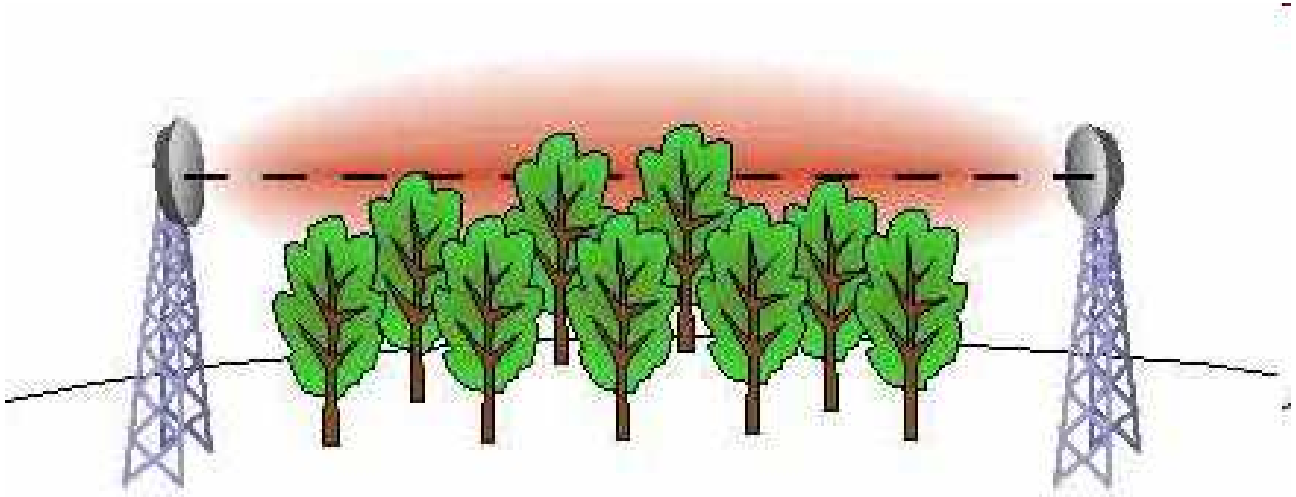
$$11^2/8 = 15.12 \text{ feet}$$

Using our guideline of rounding up, I would raise the antenna height by 15.5-16 feet to accommodate Earth bulge

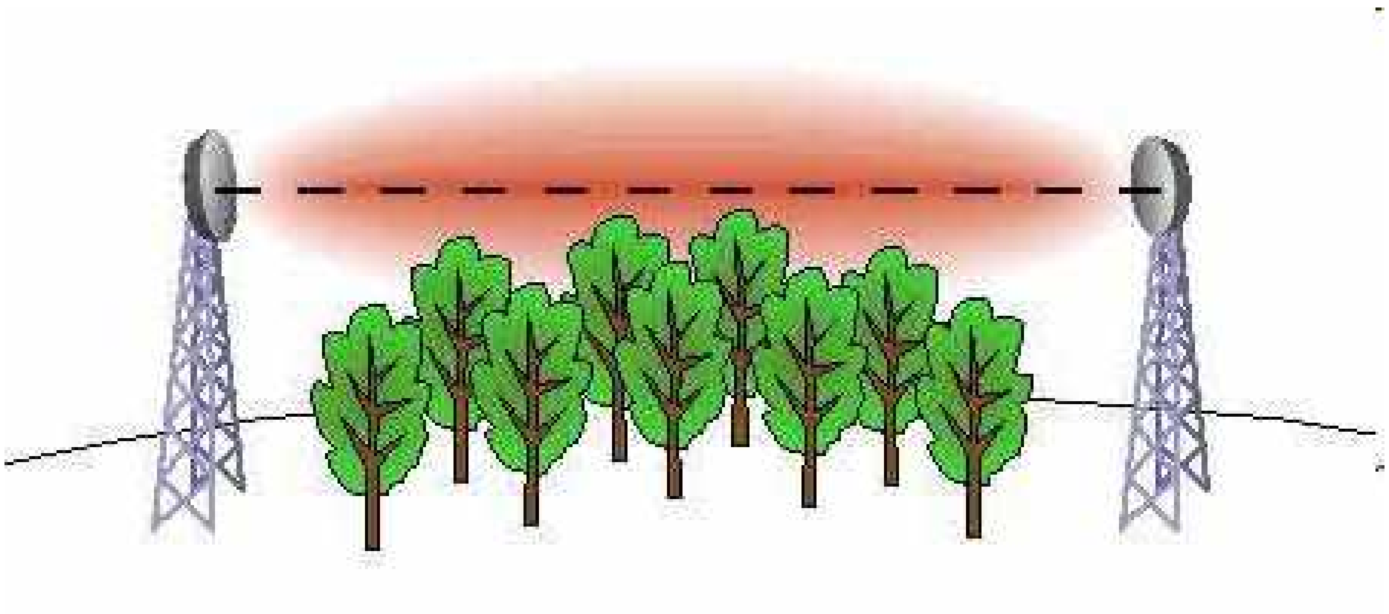
To bring all the discussion of Fresnel zones together, it is important that you learn to deal with 1FZ obstructions. If the obstructions are coming up from the ground into the 1FZ and there are no obstructions anywhere above it, you can often solve the problem by simply raising the antennas involved in the communication link. For example, if there is a forest with maximum tree height of 23 feet that is between the two antennas and there is a distance of 11 miles that must be spanned, we can calculate the needed height for the antennas, including Earth bulge, with the following formula:

$$\text{Minimum antenna height} = (57.8 \times \sqrt{(11 / (4 \times 2.4))}) + (11^2 / 8)$$

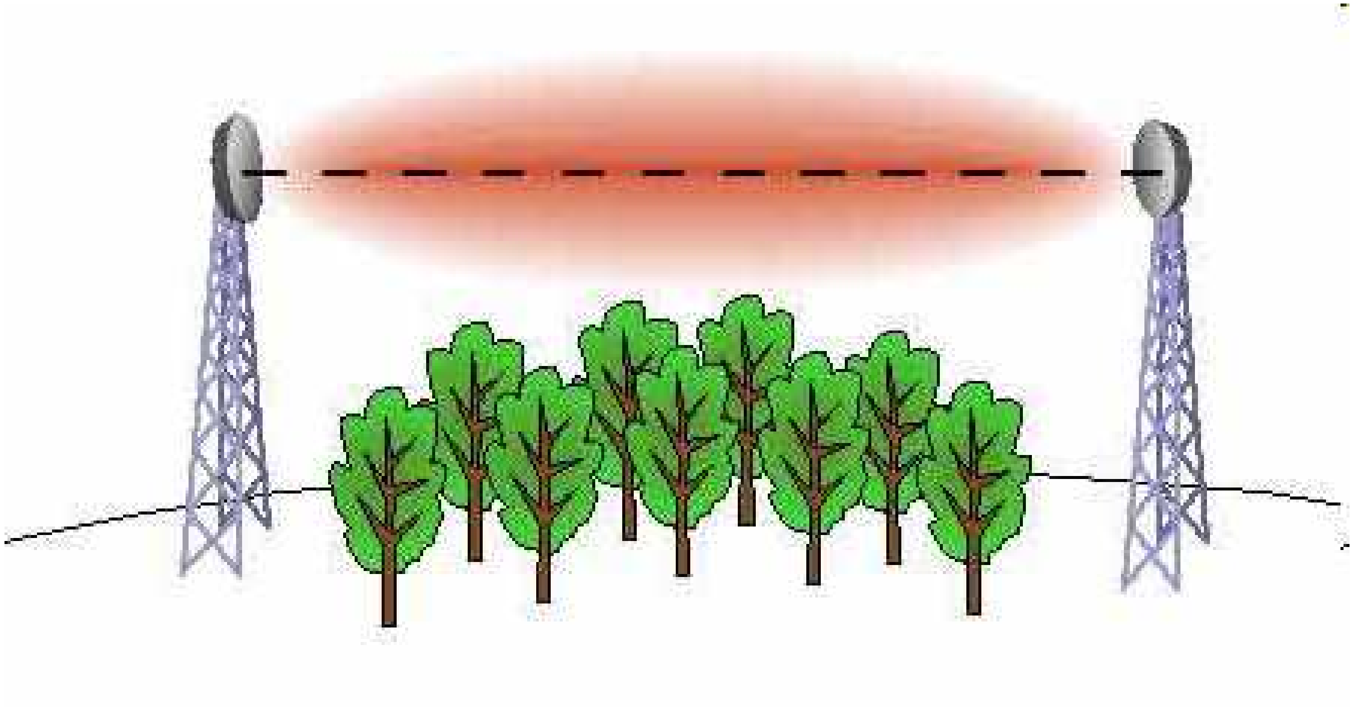
This might seem complex, at first, but it is a simple combination of the recommended 1FZ clearance formula and the Earth bulge formula. The result is 77 feet. This means you will need very high towers and you will also need to monitor the forest, though it is unlikely that the trees would grow that much more into the 1FZ in a few years.



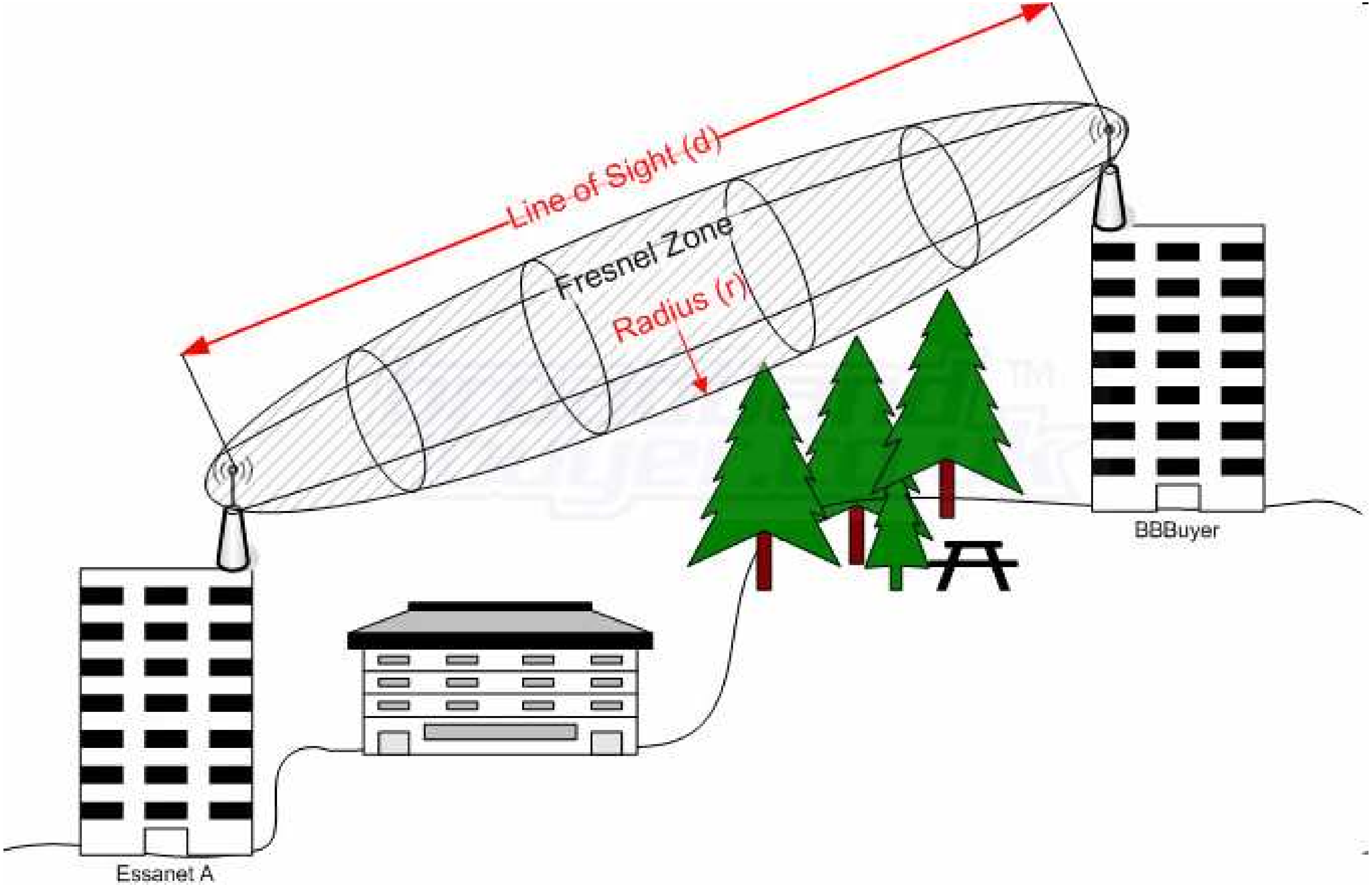
Incorrect installation, the trees obstruct the line of sight .The received signal will be severely attenuated .



Incorrect Installation, the first Fresnel zone is partially obscured. The received signal will suffer attenuation .



Correct installation. The first Fresnel zone clears the trees .


Line of Sight (d)
Fresnel Zone
Radius (r)
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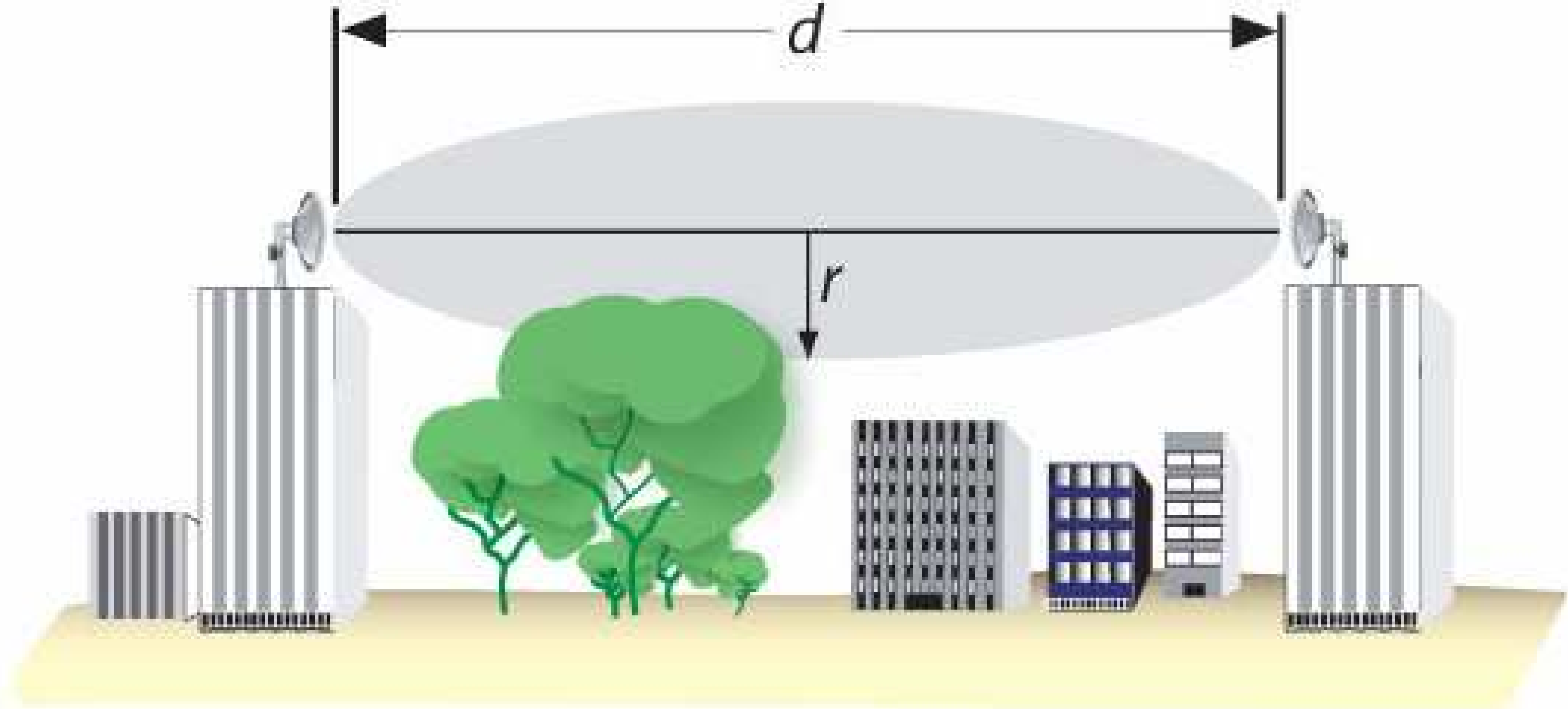

$$r = 72.6 \times \sqrt{\frac{d}{4f}}$$