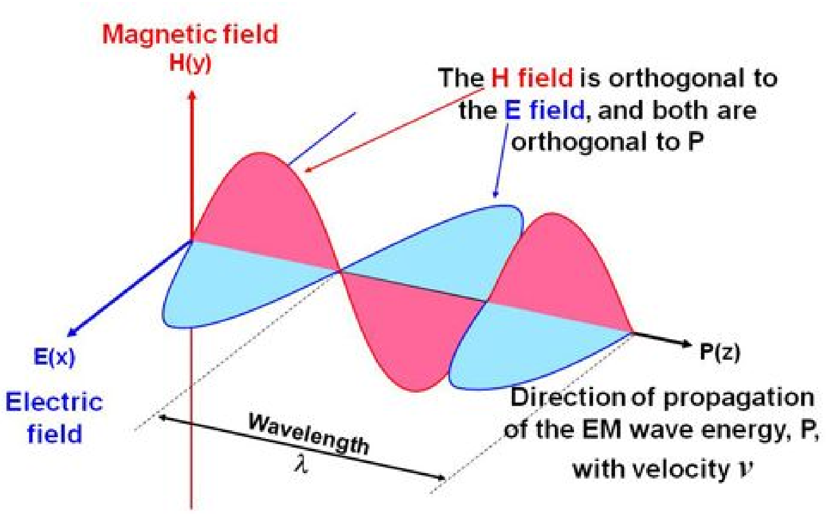
# FREE SPACE LOSS

In telecommunication, **free-space path loss** (**FSPL**) is the loss in signal strength of an electromagnetic wave that would result from a line-of-sight path through free space (usually air), with no obstacles nearby to cause reflection or diffraction. It does not include factors such as the gain of the antennas used at the transmitter and receiver, nor any loss associated with hardware imperfections. A discussion of these losses may be found in the article on link budget.




**Free-space path loss formula**

Free-space path loss is proportional to the square of the distance between the transmitter and receiver, and also proportional to the square of the frequency of the radio signal. For any type of wireless communication the signal disperses with distance. Therefore, an antenna with a fixed area will receive less signal power the farther it is from the transmitting antenna. For satellite communication this is the primary mode of signal loss. Even if no other sources of attenuation or impairment are assumed, a transmitted signal attenuates over distance because the signal is being spread over a larger and larger area. This form of attenuation is known as **free space loss**, which can be express in terms of the ratio of the radiated power to the power received by the antenna or, in decibels, by taking 10 times the log of that ratio. For the ideal isotropic antenna, free space loss is

The equation for FSPL is

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$$

where:

- $\lambda$ is the signal wavelength (in metres),
- $f$ is the signal frequency (in hertz),
- $d$ is the distance from the transmitter (in metres),
- $c$ is the speed of light in a vacuum, $2.99792458 \times 10^8$ metres per second.

This equation is only accurate in the far field where spherical spreading can be assumed; it does not hold close to the transmitter.

**Free-space path loss in decibels**

A convenient way to express FSPL is in terms of dB:

$$L_{dB} = 10\log\frac{P_t}{P_r} = 20\log\left(\frac{4\pi d}{\lambda}\right)$$

$$\begin{aligned}\text{FSPL(dB)} &= 10\log_{10}\left(\left(\frac{4\pi}{c}df\right)^2\right)\\ &= 20\log_{10}\left(\frac{4\pi}{c}df\right)\\ &= 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c}\right)\\ &= 20\log_{10}(d) + 20\log_{10}(f) - 147.55\end{aligned}$$

For other antennas, we must take into account the gain of the antenna, which yields the following free space loss equation:

$$\frac{P_t}{P_r} = \frac{(4\pi)^2(d)^2}{G_r G_t \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$$

- $G_t$ = gain of transmitting antenna
- $G_r$ = gain of receiving antenna
- $A_t$ = effective area of transmitting antenna
- $A_r$ = effective area of receiving antenna

The third fraction is derived from the second fraction using the relationship between antenna gain and effective area defined in Equation. We can recast the loss equation as

$$L_{dB} = 20\log(\lambda) + 20\log(d) - 10\log(A_t A_r)$$
$$= -20\log(f) + 20\log(d) - 10\log(A_t A_r) + 169.54 \text{ dB}$$

Thus, for the same antenna dimensions and separation, the longer the carrier wavelength (lower the carrier frequency), the higher is the free space path loss. It is interesting to compare Equations. Equation indicates that as the frequency increases, the free space loss also increases, which would suggest that at higher frequencies, losses become more burdensome. However, Equation shows that we can easily compensate for this increased loss with antenna gains. In fact, there is a net gain at higher frequencies, other factors remaining constant. Equation shows that at a fixed distance an increase in frequency results in an increased loss measured by 20log(f). However, if we take into account antenna gain, and fix antenna area, then the change in loss is measured by -20log(f) that is, there is actually a decrease in loss at higher frequencies.