LINK BUDGET AND LINK MARGIN

The various terms in the Friis formula of are often tabulated separately in a link budget, where each of the factors can be individually considered in terms of its net effect on the received power. Additional loss factors, such as line losses or impedance mismatch at the antennas, atmospheric attenuation, and polarization mismatch can also be added to the link budget. One of the terms in a link budget is the path loss, accounting for the free-space reduction in signal strength with distance between the transmitter and receiver. Path loss is defined (in dB) as

$$Lo\ (dB) = 20log\ (\ 4\pi R\ \lambda\ ) > 0$$

Note that path loss depends on wavelength (frequency), which serves to provide a normalization for the units of distance.

With the above definition of path loss, we can write the remaining terms of the Friis formula as shown in the following link budget:

Transmit power	$\mathbf{P_t}$
Transmit antenna line loss	$-L_t$
Transmit antenna gain	G_t
Path loss (free-space)	$-L_o$
Atmospheric attenuation	$-L_A$
Receive antenna gain	G_r
Receive antenna line loss	$-L_r$
Receive power	$\boldsymbol{P_r}$

We have also included loss terms for atmospheric attenuation and line attenuation. Assuming that all of the above quantities are expressed in dB (or dBm, in the case of Pt), we can write the receive power as

$$\boldsymbol{Pr\ (dBm) = Pt - Lt + Gt - Lo - LA + Gr - Lr}$$

If the transmit and/or receive antenna is not impedance matched to the transmitter/ receiver (or to their connecting lines), impedance mismatch will reduce the received power by the factor $(1 - |\Gamma|\ 2\ )$, where Γ is the appropriate reflection coefficient. The resulting impedance mismatch loss,

$$Limp(dB) = -10\log\ (1 - |\Gamma|\ 2\ ) \geq 0,$$

can be included in the link budget to account for the reduction in received power.

Another possible entry in the link budget relates to the polarization matching of the transmit and receive antennas, as maximum power transmission between transmitter and receiver requires both antennas to be polarized in the same manner. If a transmit antenna is vertically polarized, for example, maximum power will only be delivered to a vertically polarized receiving antenna, while zero power would be delivered to a horizontally polarized receive antenna, and half the available power would be delivered to a circularly polarized antenna.

In practical communications systems it is usually desired to have the received power level greater than the threshold level required for the minimum acceptable quality of service (usually expressed as the minimum carrier-to-noise ratio (CNR), or minimum SNR). This design allowance for received power is referred to as the link margin, and can be expressed as the difference between the design value of received power and the minimum threshold value of receive power:

$$Link\ Margin\ (dB) = LM = Pr - Pr(min) > 0,$$

where all quantities are in dB. Link margin should be a positive number; typical values may range from 3 to 20 dB. Having a reasonable link margin provides a level of robustness to the system to account for variables such as signal fading due to weather, movement of a mobile user, multipath propagation problems, and other unpredictable effects that can degrade system performance and quality of service. Link margin that is used to account for fading effects is sometimes referred to as fade margin. Satellite links operating at frequencies above 10 GHz, for example, often require fade margins of 20 dB or more to account for attenuation during heavy rain.