SkyPilot Link Budget Calculations – 4.9 GHz

Link budget defines the amount of power available in a communication link for transmission loss through the path, whether the loss is through the air or through obstructions like trees and buildings. With a known link budget, the range of a communication link can be determined given a fixed path loss and fade margin. Because of the large variation in path loss models for propagation in real world environments, the link budget becomes a more easily comparable specification for evaluation of communication systems. It is generally true that a higher link budget will provide longer range. For this reason, link budget is an important specification for all RF deployments.

The basic equation for link budget is a fairly simple formula when using units of power in dB.

Link Budget =
Transmit Power + Transmit Antenna Gain + Receive Antenna Gain - Receiver Sensitivity

Transmit Power

"Transmit power" is the power coming out of the radio/power amplifier and into the antenna. Transmit power is normally measured in dBm. Although many companies highlight peak power, it is not accurate to use peak power for link budget calculations. Instead, link budget calculations should always use average power. If you've ever used a stereo with a power output display, you should be able to understand the difference between peak power and average power. A general rule of thumb is that the average power is about 5 dB (OFDM) less than the peak power. As an example, the FCC limits the maximum peak power in the license 4.9 GHz frequency band (4.940 to 4.990 GHz) to 1 W/30 dBm, which would translate to an average power for link budget calculations around 25-27 dBm.

The 4.9 GHz access point in SkyPilot's SkyExtender DualBand and TriBand products is FCC rated at an average power of about 26 dBm and the average power output changes slightly depending on the modulation. For the lower modulations (BPSK & QPSK), the output can be driven harder so the average power is 26 dBm. For the higher modulations (QAM), the average power backs off to between 21 and 24 dBm. This is generally referred to as amplifier back off.

Antenna Gain

"Antenna gain" represents the gain of the antenna relative to a single point antenna radiating evenly in all directions (sphere). So the gain is actually a measure of how well focused the antenna is at radiating the signal. The important thing about antennas is that the larger the antenna the larger the gain and the smaller the focus. Improvements in antenna are especially beneficial to link budgets because they are counted twice, once for the transmit antenna and once for the receive antenna. The 4.9 GHz antenna on the SkyExtender DualBand or TriBand has 9.5 dBi of antenna gain.

SkyPilot Antenna Characteristics

Product	SkyExtender DualBand or SkyExtender TriBand
Antenna Gain	9.5 dBi
Azimuth beam width	360°
Elevation beam width	8°
Antenna down tilt	6°

Receiver Sensitivity

"Receiver sensitivity" is a measure of the minimum signal level that can be received by a radio. The word "received" has to be defined in terms of the quality of the link. For our system we use a 10% packet error rate (PER) as the metric for link quality (this is the same metric used by RF chip companies as well). Testing is done with no external interference and the signal power is reduced until a 10% PER occurs, at which time the average power is then measured. Receiver sensitivity changes with modulation and data rates as shown in the table below:

SkyPilot Measured Receiver Sensitivity

Data Rate (802.11a)	Modulation Format	Receiver Sensitivity (all numbers +/- 2 dBm)
6 Mbps	BPSK – 1/2	-94 dBm
9 Mbps	BPSK – 3/4	-93 dBm
12 Mbps	QPSK – 1/2	-91 dBm
18 Mbps	QPSK – 3/4	-90 dBm
24 Mbps	16QAM – 1/2	-86 dBm
36 Mbps	16QAM – 3/4	-83 dBm
48 Mbps	64QAM – 1/2	-77 dBm
54 Mbps	64QAM – 3/4	-74 dBm

Link Budget Performance Summary

To calculate the link budget, the Wi-Fi client's transmit power, transmit antenna gain, receive antenna gain, and receiver sensitivity need to be included. The following table can help calculate the link budget between SkyPilot's SkyExtender DualBand and an IEEE 802.11a client over the 4.9 GHz frequency. The sample below uses a 26 dBm 4.9 GHz 802.11a client with a 5 dBi antenna.

Modulation Rate (802.11a)	Transmit Power (all +/- 1 dB)	Transmit Antenna Gain	Receive Antenna Gain	Receiver Sensitivity (all +/- 2 dB)	Link Budget
6 Mbps	26 dBm	9.5 dBi	5 dBi	-94 dBm	134.5 dBm
9 Mbps	26 dBm	9.5 dBi	5 dBi	-93 dBm	133.5 dBm
12 Mbps	26 dBm	9.5 dBi	5 dBi	-91 dBm	131.5 dBm
18 Mbps	26 dBm	9.5 dBi	5 dBi	-90 dBm	130.5 dBm
24 Mbps	26 dBm	9.5 dBi	5 dBi	-86 dBm	126.5 dBm
36 Mbps	24 dBm	9.5 dBi	5 dBi	-83 dBm	123.5 dBm
48 Mbps	22 dBm	9.5 dBi	5 dBi	-77 dBm	117.5 dBm
54 Mbps	21 dBm	9.5 dBi	5 dBi	-74 dBm	114.5 dBm
6 Mbps	26 dBm	5 dBi	9.5 dBi	-94 dBm	134.5 dBm
9 Mbps	26 dBm	5 dBi	9.5 dBi	-93 dBm	133.5 dBm
12 Mbps	26 dBm	5 dBi	9.5 dBi	-91 dBm	131.5 dBm
18 Mbps	26 dBm	5 dBi	9.5 dBi	-90 dBm	130.5 dBm
24 Mbps	26 dBm	5 dBi	9.5 dBi	-86 dBm	126.5 dBm
36 Mbps	24 dBm	5 dBi	9.5 dBi	-83 dBm	123.5 dBm
48 Mbps	22 dBm	5 dBi	9.5 dBi	-77 dBm	117.5 dBm
54 Mbps	21 dBm	5 dBi	9.5 dBi	-74 dBm	114.5 dBm

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