SILVERNET
WIRELESS-NETWORK-SOLUTIONS

Frequently Asked Questions

60GHz

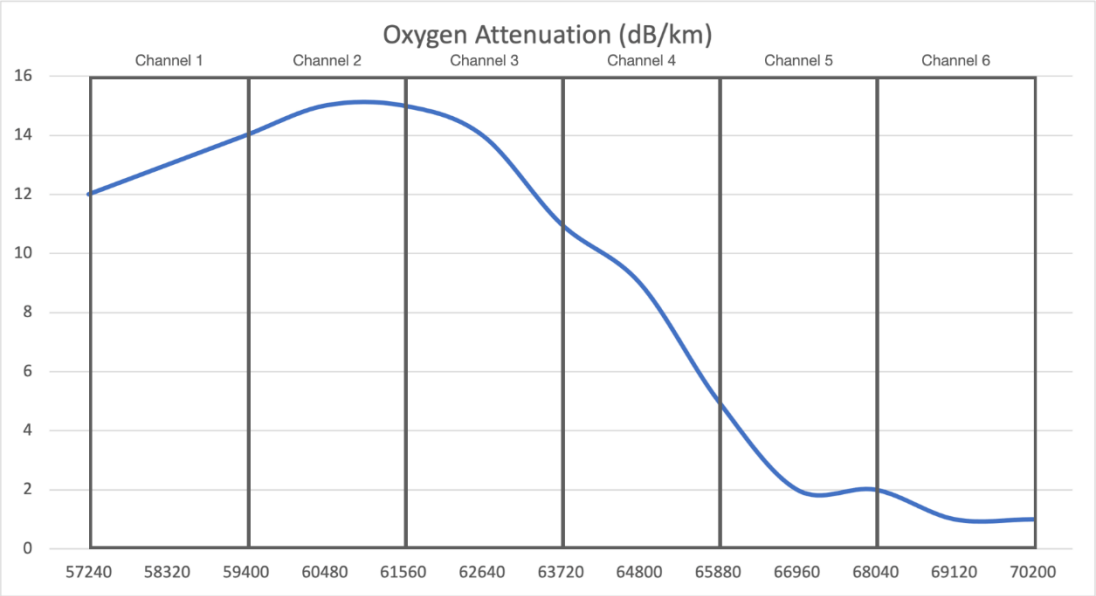
HOW IS THE 60GHZ SPECTRUM AFFECTED BY OXYGEN?

Both rain and oxygen can heavily impact signal levels in the 60GHz band.

Oxygen absorbs the signal in the lower half of the unlicensed 60GHz band with a peak at channels 2 and 3 of around 15dB/km at sea level.

This amount varies based on altitude since altitude also has an impact on the amount of oxygen in the path.

Channel 1 is less impacted by oxygen absorption at around 12dB/km and channels 5 and 6 are minimally impacted by oxygen absorption as shown in the graph below:



CHANNEL PLANNING

These physical characteristics can be very useful when planning deployments:

- For **high densities of shorter links** using the channels with high oxygen absorption results in less self-interference and a higher amount of channel reuse since the oxygen is eliminating the signal quickly past the usable range.
- **For longer links**, the upper channels enable longer connections.

Summary: the 60 GHz upper band channels are less affected by oxygen absorption than the lower channels.

HOW IS THE 60GHZ SPECTRUM AFFECTED BY RAIN?

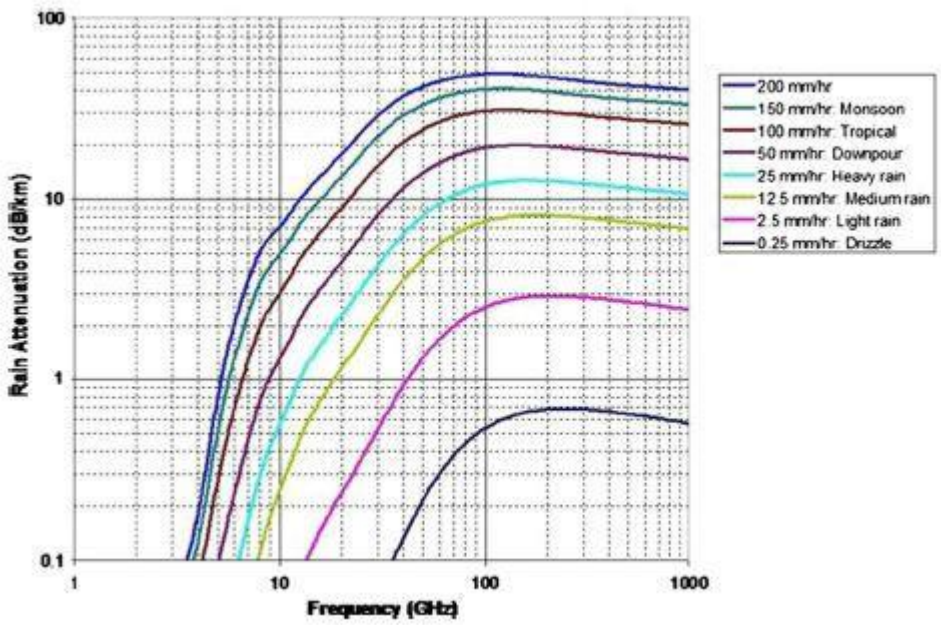
RAIN FADE & 60 GHZ

All wireless links that operate at a frequency above 6GHz are attenuated by rain to some degree. The amount of attenuation depends on:

1. The **frequency of operation**: the higher the frequency, the higher the attenuation in general
2. The **intensity of the rain**: the higher the intensity, the higher the attenuation in general
3. The **length of the path** where rain is falling

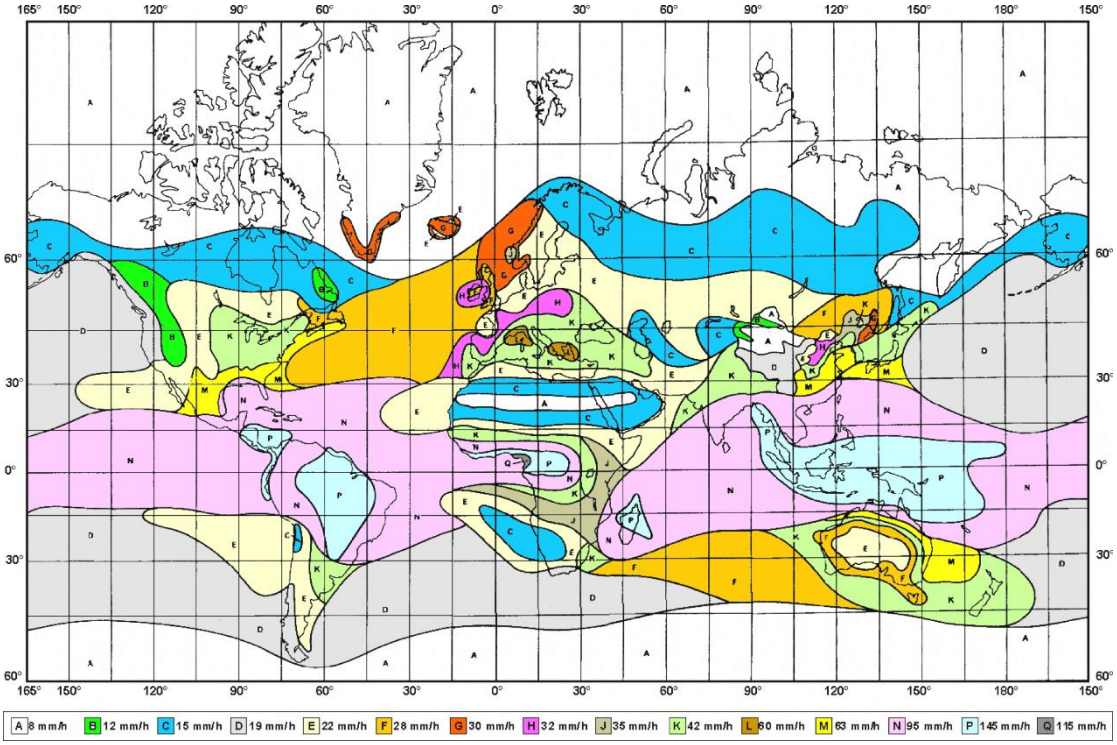
FREQUENCY & RAIN FADE FACTORS

The first 2 factors are fairly straightforward. This chart below shows the amount of attenuation based on frequency of operation and the intensity of the rainfall expressed in dB/km of attenuation:



Rain attenuation grows based on frequency until around 100GHz where it is flat-to-slightly-lower as frequency is increased beyond 100GHz.

There are several models that can be used to calculate the rain rate for a given region. The ***ITU model*** assigns rain zones for different geographic regions and then uses probabilities and a formula to provide attenuation based on link availability.



While this model can be useful, there are other ways to look at this that we feel provides a much better understanding of the chances for a link to drop.

For the US and a few select other regions, NOAA provides very detailed rainfall data that can be used to calculate if a link will go down during a rain storm, how often that type of rain fall might occur, and the duration.

To access the data for your area:

1. Simply click on your state
2. Change the dropdown at the top of the page to "Precipitation Intensity"
3. Input the address you wish to analyse.

The table at the bottom of the page will update accordingly. An example for San Diego is provided here for reference:

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**1.39** (1.16-1.69)	**1.99** (1.66-2.40)	**2.71** (2.26-3.29)	**3.28** (2.70-4.00)	**3.98** (3.18-5.04)	**4.50** (3.52-5.83)	**5.00** (3.80-6.65)	**5.50** (4.07-7.51)	**6.14** (4.34-8.76)	**6.61** (4.52-9.78)
10-min	**1.00** (0.840-1.21)	**1.43** (1.19-1.72)	**1.94** (1.62-2.36)	**2.35** (1.94-2.87)	**2.86** (2.28-3.61)	**3.23** (2.52-4.18)	**3.59** (2.73-4.76)	**3.94** (2.92-5.39)	**4.40** (3.11-6.28)	**4.74** (3.24-7.01)
15-min	**0.808** (0.676-0.976)	**1.15** (0.960-1.39)	**1.57** (1.31-1.90)	**1.89** (1.56-2.31)	**2.30** (1.84-2.92)	**2.60** (2.03-3.37)	**2.89** (2.20-3.84)	**3.18** (2.35-4.34)	**3.55** (2.51-5.06)	**3.82** (2.61-5.65)
30-min	**0.554** (0.462-0.668)	**0.788** (0.658-0.952)	**1.07** (0.896-1.30)	**1.30** (1.07-1.58)	**1.58** (1.26-2.00)	**1.78** (1.39-2.31)	**1.98** (1.51-2.63)	**2.18** (1.61-2.98)	**2.43** (1.72-3.47)	**2.62** (1.79-3.87)
60-min	**0.390** (0.326-0.470)	**0.554** (0.463-0.670)	**0.756** (0.630-0.917)	**0.912** (0.753-1.12)	**1.11** (0.886-1.41)	**1.25** (0.980-1.62)	**1.40** (1.06-1.85)	**1.53** (1.13-2.10)	**1.71** (1.21-2.44)	**1.84** (1.26-2.73)
2-hr	**0.271** (0.227-0.328)	**0.370** (0.309-0.447)	**0.491** (0.409-0.595)	**0.584** (0.483-0.715)	**0.705** (0.562-0.892)	**0.792** (0.619-1.03)	**0.878** (0.668-1.17)	**0.962** (0.711-1.31)	**1.07** (0.758-1.53)	**1.15** (0.786-1.70)
3-hr	**0.217** (0.182-0.263)	**0.291** (0.243-0.352)	**0.383** (0.319-0.464)	**0.454** (0.375-0.554)	**0.545** (0.435-0.690)	**0.611** (0.478-0.791)	**0.676** (0.515-0.898)	**0.741** (0.547-1.01)	**0.823** (0.583-1.17)	**0.884** (0.604-1.31)
6-hr	**0.144** (0.120-0.174)	**0.189** (0.158-0.228)	**0.245** (0.204-0.297)	**0.289** (0.238-0.353)	**0.346** (0.276-0.437)	**0.387** (0.302-0.501)	**0.428** (0.326-0.568)	**0.469** (0.347-0.640)	**0.522** (0.369-0.744)	**0.561** (0.383-0.829)
12-hr	**0.092** (0.077-0.111)	**0.119** (0.099-0.143)	**0.153** (0.127-0.185)	**0.180** (0.148-0.220)	**0.215** (0.171-0.272)	**0.241** (0.188-0.312)	**0.267** (0.203-0.354)	**0.293** (0.217-0.401)	**0.327** (0.232-0.467)	**0.353** (0.241-0.522)
24-hr	**0.058** (0.051-0.067)	**0.074** (0.065-0.086)	**0.095** (0.083-0.111)	**0.112** (0.097-0.132)	**0.135** (0.113-0.163)	**0.152** (0.125-0.187)	**0.168** (0.136-0.213)	**0.186** (0.146-0.241)	**0.208** (0.158-0.281)	**0.226** (0.166-0.314)
2-day	**0.035** (0.030-0.040)	**0.045** (0.039-0.052)	**0.058** (0.050-0.067)	**0.068** (0.059-0.080)	**0.082** (0.069-0.099)	**0.093** (0.076-0.115)	**0.103** (0.083-0.131)	**0.114** (0.090-0.148)	**0.129** (0.098-0.173)	**0.140** (0.103-0.195)
3-day	**0.026** (0.022-0.030)	**0.033** (0.029-0.039)	**0.043** (0.038-0.050)	**0.051** (0.044-0.060)	**0.062** (0.052-0.075)	**0.070** (0.058-0.087)	**0.078** (0.063-0.099)	**0.087** (0.068-0.112)	**0.098** (0.074-0.132)	**0.107** (0.078-0.148)
4-day	**0.021** (0.018-0.024)	**0.027** (0.024-0.032)	**0.035** (0.031-0.041)	**0.042** (0.036-0.050)	**0.051** (0.043-0.062)	**0.058** (0.048-0.072)	**0.065** (0.052-0.082)	**0.072** (0.056-0.093)	**0.081** (0.062-0.109)	**0.088** (0.065-0.123)
7-day	**0.014** (0.012-0.016)	**0.018** (0.016-0.021)	**0.024** (0.021-0.028)	**0.029** (0.025-0.034)	**0.035** (0.029-0.042)	**0.040** (0.033-0.049)	**0.045** (0.036-0.056)	**0.049** (0.039-0.064)	**0.056** (0.042-0.075)	**0.061** (0.045-0.085)
10-day	**0.011** (0.009-0.012)	**0.014** (0.012-0.016)	**0.019** (0.016-0.022)	**0.022** (0.019-0.026)	**0.027** (0.023-0.033)	**0.031** (0.025-0.038)	**0.035** (0.028-0.044)	**0.038** (0.030-0.050)	**0.043** (0.033-0.058)	**0.047** (0.035-0.066)
20-day	**0.006** (0.006-0.007)	**0.009** (0.007-0.010)	**0.011** (0.010-0.013)	**0.014** (0.012-0.016)	**0.017** (0.014-0.020)	**0.019** (0.016-0.023)	**0.021** (0.017-0.027)	**0.023** (0.018-0.030)	**0.026** (0.020-0.036)	**0.029** (0.021-0.040)
30-day	**0.005** (0.004-0.006)	**0.007** (0.006-0.008)	**0.009** (0.008-0.010)	**0.011** (0.009-0.012)	**0.013** (0.011-0.016)	**0.015** (0.012-0.018)	**0.016** (0.013-0.021)	**0.018** (0.014-0.023)	**0.020** (0.015-0.028)	**0.022** (0.016-0.031)
45-day	**0.004** (0.003-0.005)	**0.005** (0.005-0.006)	**0.007** (0.006-0.008)	**0.008** (0.007-0.010)	**0.010** (0.008-0.012)	**0.011** (0.009-0.014)	**0.012** (0.010-0.016)	**0.014** (0.011-0.018)	**0.016** (0.012-0.021)	**0.017** (0.012-0.023)
60-day	**0.003** (0.003-0.004)	**0.005** (0.004-0.005)	**0.006** (0.005-0.007)	**0.007** (0.006-0.008)	**0.008** (0.007-0.010)	**0.010** (0.008-0.012)	**0.011** (0.009-0.013)	**0.012** (0.009-0.015)	**0.013** (0.010-0.017)	**0.014** (0.010-0.020)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

How to read this chart

This chart is useful for understanding how likely a link is to drop.

- On the left side, a duration for the rainfall is listed
- Across the top you'll find the frequency of reoccurrence.
- The values in the table are rain rates in terms of inches per hour.

For most cases, the **5- or 10-min duration and the 2 or 5 year reoccurrence is most useful.**

This number should be converted to mm/hr and can then be used in the SilverNet Ltd link calculator to understand if the link is robust or not. For example, a 5 min duration / 2-year reoccurrence for San Diego is 1.99 in/hr or 50.5 mm/hr.

Using the link calculator, we can see what this means in terms of link attenuation per km:

Attenuation due to rain (dB/km)

Ch. 1	Ch. 2	Ch. 3	Ch. 4	Ch. 5	Ch. 6
16	16	16	17	17	17

Input rain rate (mm/hr) Help me choose

50.5 Downpour

If the link is only 500m, this would only equate to 8-9dB of rain fade depending on the channel.

Again, using the link calculator, we can see that it is very unlikely that a 500m link in San Diego will ever go down due to rain:

Channel

1 2 3 4 5 6

Selected channel: 5 (66960 MHz)

Loss due to O^2: **LOW**

Target distance (m)

500

Target modulation

MCS1 300 Mbps | MCS4 900 Mbps | MCS8 1750 Mbps | MCS10 2300 Mbps

» RESULTS

This link is possible in dry conditions, and has a signal budget of 8 dBm for rain fade.

Rx sensitivity	Expected RSSI	Total signal budget	Coverage area
-68 dBm	-60 dBm	8 dBm	0.3 km^2

At the lowest modulation (MCS1), this link can withstand **a downpour (63 mm/hr)**, or max pathloss of 20.0 dBm/km, given the selected distance and channel.

From the results, this link can withstand a rain rate of 63 mm/hr (2.48 in/hr).

According to the chart for San Diego listed above, that's only likely to occur every 5 years with a max duration of 5 minutes (or every 10-25 years with a max duration of 10 minutes).

PATH LENGTH FACTOR

The last factor (length of path) is a bit more nuanced. The attenuation by rain will occur where there is rainfall in the path itself. Depending on the rain distribution, this *may or may not be the entire path*.

Also, if rainfall typically occurs in particular orientations (for example, as a line that runs north to south), links that are perpendicular may have lower attenuation simply because the entire path does not have rainfall occurring at the same time.

It is also important to note that SilverNet Ltd radios can use lower modulations in periods of rain in order to keep a link working at lower capacity levels. Once the rainfall has reduced or stopped, the full "dry link" capacity will be restored.

The SilverNet Ltd link calculator tool can help to provide the amount of link budget estimated for a given distance.

This, in turn, can be used to estimate how much additional attenuation the link can withstand before losing connection - and a corresponding rain intensity can be derived.