

Rain Fade Considerations in the Design of Millimeter Wave Radio Links White Paper

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Making Millimeter Wave Ubiquitous

Abstract

Millimeter wave point-to-point radio links are gaining traction for transporting high-speed digital information, especially as data rates approach and exceed 1 Gbps. Proper planning and design for the millimeter wave link requires knowledge of the local environment to assure reliable operation. The fundamental concept used to determine link reliability is known as service availability. Rain fade can affect millimeter wave wireless link availability if the fade is severe enough to interrupt link service.

This paper outlines these concepts and provides a methodology to predict link availability, taking into consideration the impact of rain fade.

Millimeter Wave Link Budget and Fade Margin

Millimeter wave radio transmission is naturally attenuated by distance of the transmission, known as path loss. For a known millimeter wave link design, the transmit power, antenna gain, and receive sensitivity are factors that combine with the path loss to determine the maximum range or distance for the link. From these parameters in a given product design, a link budget is derived. It's typical and most convenient to specify the link budget in decibels or dB. The link budget is the maximum allowed path loss under ideal conditions.

As an example, the Vubiq Networks HaulPass V60s™ 60 GHz point-to-point product has a link budget of 142 dB. With zero rain fade, this number yields a range of 750 meters with a 5.2 dB margin. If the link is installed at a range of 500 meters, then there will be a margin of 12.5 dB left to handle even more rain fade.

Range (meters)	Path Loss (dB)	Margin (dB)
750	136.8	5.2
700	135.4	6.6
650	134.0	8.0
600	132.6	9.4
550	131.1	10.9
500	129.5	12.5
450	127.8	14.2
400	126.1	15.9
350	124.1	17.9
300	122.1	19.9
250	119.7	22.3
200	117.0	25.0
150	113.8	28.2
100	109.5	32.5

Figure 1. Range, Path Loss and Margin for the HaulPass V60s

Once the link budget and margin are known for given ranges of operation, rain fade can be taken into account to determine the expected link availability.

Rain Attenuation

Signal fade due to rain attenuation is a well-known and studied phenomenon. Figure 2 shows a graph of specific attenuation versus frequency at various rain rates, with 60 GHz and 80 GHz highlighted. Rain rate means how much rain falls in a given time period, and is measured in millimeters of rain per hour (mm/h). Divide these numbers by 25.4 if inches/hour is desired.

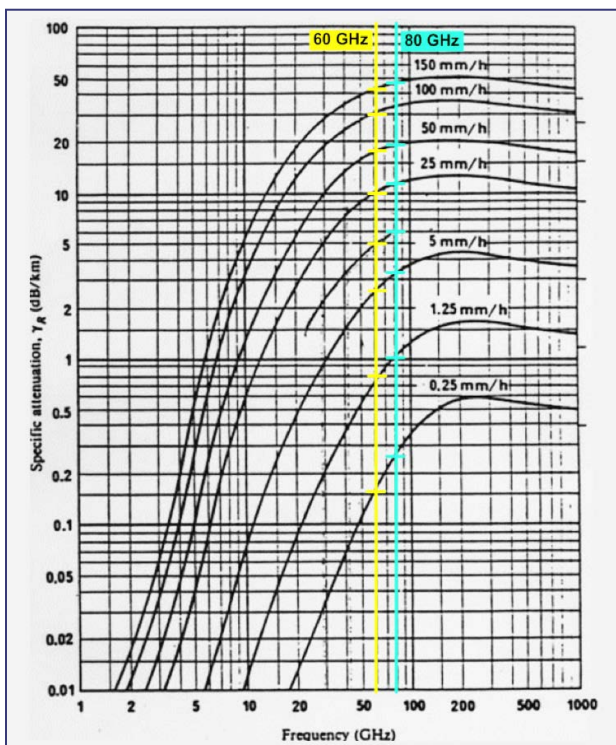


Figure 2. Attenuation vs Frequency at Different Rain Rates¹

For example, at 25 mm/h (close to 1"/h), the attenuation due to rain at 60 GHz is 10 dB. If a V60s link were installed at 350 meters range, from Figure 1 the margin at this range is 17.9 dB. At 25 mm/h the rain would not affect operation since the rain attenuation of 10 dB is less than the margin at 17.9 dB.

Predicting Link Availability

Rain rate probabilities for a given geographical location can easily be derived from the International Telecommunications Union (ITU) rain zone map. Figure 3 shows the global ITU rain zone map, and Figure 4 shows a close-up of the southwestern U.S. and Mexico. To predict the rain fade probabilities for a given location, the area is first located on the rain zone map.

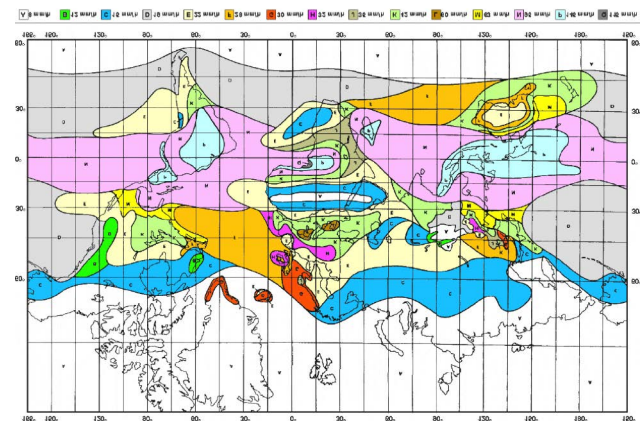


Figure 3. ITU Rain Zones, Global²

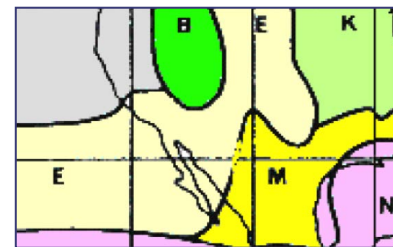


Figure 4. ITU Rain Zones, Southwestern U.S./Mexico Close-Up

Percentage of time (%)	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
1.0	<0.1	0.5	0.7	2.1	0.6	1.7	3	2	8	1.5	2	4	5	12	24
0.3	0.8	2	2.8	4.5	2.4	4.5	7	4	13	4.2	7	11	15	34	49
0.1	2	3	5	8	6	8	12	10	20	12	15	22	35	65	72
0.03	5	6	9	13	12	15	20	18	28	23	33	40	65	105	96
0.01	8	12	15	19	22	28	30	32	35	42	60	63	95	145	115
0.003	14	21	26	29	41	54	45	55	45	70	105	95	140	200	142
0.001	22	32	42	42	70	78	65	83	55	100	150	120	180	250	170

Figure 5. Rainfall Intensity Exceeded (mm/h) vs. Rain Zones

As an example, let's design a 350 meter V60s link to be installed in southern California with an uptime availability of 99.99% ("four nines"). The rain zone for this area is ITU Zone E. There is a table of rain rate probabilities published in the ITU document, shown in Figure 5. A 99.99% availability means the unavailability or downtime allowed needs to be less than .01%. For Zone E, the 0.01% row shows that the rain rate will exceed a value of 22 mm/h. Checking back at Figure 2, a rain rate of 22 mm/h will produce an additional attenuation, or rain fade, of slightly less than 10 dB/km.

Since the desired range is 350 meters, or 0.35 km, the actual attenuation will be $0.35 \times 10 \text{ dB} = 3.5 \text{ dB}$ (this is because the rain attenuation is specified in dB/km).

The link budget chart for the V60s at Figure 1 shows that a 350 meter link will have a margin of 12.6 dB. The example link should operate with greater than 99.99% uptime since the margin is greater than the rain fade of approximately 3.5 dB for this link at 22 mm/h rain rate.

Conclusion

Knowing the parameters for a millimeter wave link and understanding how to use the ITU rain zone data enables link design with predictable performance and availability.

Footnotes:

1. FCC Office of Engineering and Technology, Bulletin Number 70 https://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet70/oet70.pdf
2. Recommendation ITU-R PN.837-1 https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.837-1-199408-S!!PDF-E.pdf
3. Recommendation ITU-R PN.837-1 https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.837-1-199408-S!!PDF-E.pdf



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