Microwave Fixed Service Fade Margin Calculation

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Weather Related Fading

Fading outages on a microwave radio can come from flat fading, dispersive fading and rain fading. Both flat fading and dispersive fading are quite frequency dependent. Consequently, for microwave radio communication systems using Frequency Division Duplex (FDD), like most systems in the 6 GHz bands, where a different carrier frequency is used for each direction of communication, outages from these fading mechanisms are uncorrelated in each direction. Therefore, the TIA-10 strategy to compute total fading outage on FDD microwave paths involves computing the expected one-way flat fading outage time, one-way dispersive fading outage time and rain fading outage time. The total outage on the two-way FDD path is then the sum of rain outage time plus two times the one-way dispersive and flat fading outage times. See ANSI TIA-10 section 10.5.

For longer paths operating at frequencies below 10 GHz, rain fading is usually negligible compared to flat and dispersive fading. Outage from dispersive fading can be reduced by using adaptive equalizers in the radio receiver. The equalizers in modern radios are usually capable of reducing outage from dispersive fading to a small fraction of the flat fading outage. Outage from flat fading depends, among other factors, on the flat fade margin of the microwave radio path. Received interference can reduce the flat fade margin and increase outage times.

Fade Margin and Interference

To properly decode a received signal utilizing a particular modulation, a minimum Signal to Interference plus Noise Ratio (SINR) is required. The flat fade margin on a microwave radio path is the difference, in dB, between the actual fair weather SINR and the required minimum SINR. The fair weather SINR, and consequently the fade margin, will be reduced if the receiver is subjected to interference power. If n is the receiver noise power and i is its interference power, both in mW, the noise plus interference power in dBm is:

$$10\log_{10}(n+i) = 10\log_{10}[n(1+i/n)] = 10\log_{10}(n) + 10\log_{10}(1+i/n)$$

Therefore, the increase in noise plus interference power expressed in dB, relative to just the noise power is given by the term $10\log_{10}(1+i/n)$. This is the amount, in dB, that the radio fade margin is decreased by interference. Expressing i/n in dB, so that $I/N \equiv 10\log_{10}(i/n)$, the dB reduction in fade margin due to interference is given by:

$$\Delta FM = 10\log_{10}\left(1+10^{0.1\cdot I/N}\right)$$

This fade margin reduction, ΔFM, is tabulated below for select I/N values from -10 dB to +10 dB.

I/N [dB]	-10	-8	-6	-5	-4	-3	-2	-1	+0	+1	+2	+3	+4	+5	+6	+8	+10
ΔFM [dB]	0.4	0.6	1.0	1.2	1.5	1.8	2.1	2.5	3.0	3.5	4.1	4.8	5.5	6.2	7.0	8.6	10.4

Table 1 - Fade Margin Reduction for Various I/N Values

One-way Flat Fading

According to TIA-10, the expected number of seconds of one-way outage due to flat fading on a point-to-point microwave path without diversity is proportional to $10^{-FFM/10}$ where FFM is the flat fade margin in dB. For a microwave path with space diversity the outage is proportional to $10^{-2FFM/10}$. These relationships can be seen by examining the equations in TIA-10 section 10.6 as discussed next. These formulas are valid for predicting percentage outages less than about 0.2% (~17.5 hr/yr or 63,000 sec/yr).

The expected number of seconds of outage per year on a point-to-point microwave path, in one direction, due to flat multipath fading, T_F, is given by the following equation in TIA-10 section 10.6.

$$T_F = \frac{T_S}{I_F} R \times 10^{-FFM/10} = \frac{T_S}{I_F} c \left(\frac{50}{w}\right)^{1.3} \frac{f}{4} D^3 \times 10^{-5-FFM/10}$$

Since the fade occurrence rate is given by

$$R = c \left(\frac{50}{w}\right)^{1.3} \frac{f}{4} D^3 \times 10^{-5}$$

Where

T_S	Seconds in annual fading season
I_F	Diversity improvement factor
R	Fade occurrence rate
c	Location based C factor
w	Terrain roughness in ft
f	Frequency in GHz
D	Path length in miles

The number of seconds in an annual fading season is given by:

$$T_S = 8 \times 10^6 \frac{t}{50}$$

Where t is the average annual Fahrenheit temperature of the area where the path is located under the constraint that $35 < t < 75$.

The terrain roughness is a measure of the standard deviation of terrain heights along the propagation path under the constraint that $20 \le w \le 140$.

For a microwave radio path that does not employ any type of diversity $I_F = 1$.

Consequently, for a point-to-point microwave radio system without diversity, the ratio of one-way flat fading outage when it experiences interference to the same path without interference is:

$$\rho_{ND} \equiv \frac{10^{-(FFM-\Delta FM)/10}}{10^{-FFM/10}} = 10^{\Delta FM/10}$$

Where ΔFM is the fade margin reduction in dB caused by the interference.

For a path using space diversity

$$I_F = 7 \times 10^{-5} \eta s^2 (f/D) 10^{(G_D - G_P)/10} \times 10^{FFM/10}$$

Provided that $1 \leq I_F \leq 200$ and where:

η	Switching hysteresis efficiency $0 < \eta \leq 1$
s	Antenna spacing in ft
G_P	Gain of Primary RX antenna in dBi
G_D	Gain of Diversity RX antenna in dBi

Hence for the space diversity case

$$T_F = \frac{T_S}{I_F} R \times 10^{-FFM/10} = \frac{T_S R}{7 \times 10^{-5} \eta s^2 (f/D) 10^{(G_D - G_P)/10} \times 10^{FFM/10}} \times 10^{-FFM/10}$$
$$= T_S \frac{c(50/w)^{1.3} D^4}{28 \eta s^2 10^{(G_D - G_P)/10}} \times 10^{-2FFM/10}$$

Assuming the same interference power is received by both the primary and diversity receive antennas, there is again a simple relationship for the ratio of one-way flat fading outage with interference to that without interference. This ratio is given by:

$$\rho_{SD} \equiv \frac{10^{-2(FFM-\Delta FM)/10}}{10^{-2FFM/10}} = 10^{2\Delta FM/10}$$

Where ΔFM is the reduction of fade margin on the primary and diversity receivers due to interference.

Total Fading Outage

Typically, 6 GHz microwave paths are engineered in a symmetric manner, such that the one-way flat fading outage, without interference, is the same for each direction of transmission. It is also often the case that the outage on a 6 GHz path is dominated by flat fading, compared to dispersive and rain fading. If both these conditions hold, it is possible to estimate the effect of interference to the total outage on the path. For this situation—in the absence of other interference—nearly half the outage is due to flat fading in one direction of transmission and half the outage due to flat fading in the other direction. Assuming only interference into the

receiver at one end of the path, the flat fading outage in that direction will be increased by the ρ scale factor. This approximation estimates the ratio of the total outage with this interference to the total outage without interference as $(1 + \rho)/2$.

The table below lists the one-way and estimated total outage scale factors for various reductions of fade margin in one direction of transmission due to interference. As can be seen in the table, just a few dB reduction in fade margin has a significant effect on outage time. For a mere 3 dB reduction in fade margin ($I/N = 0$ dB) on one end of a path without diversity, the expected total outage time increases by about 50%. For a path with space diversity the same 3 dB loss of fade margin at one end increases the expected total outage time by almost 150%.

No Diversity			**Space Diversity**		
ΔFM [dB]	One-way	Total	ΔFM [dB]	One-way	Total
1	1.26	1.13	1	1.58	1.29
2	1.58	1.29	2	2.51	1.76
3	2.00	1.50	3	3.98	2.49
5	3.16	2.08	5	10.00	5.50
7	5.01	3.01	7	25.12	13.06
10	10.00	5.50	10	100.00	50.50

Table 2 - One-way and Total Outage Scale Factors vs Fade Margin Reduction