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TITLE: **RADIO LAN SYSTEM POWER BUDGETS AND LEVELS**

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OVERVIEW

It is helpful to estimate transmitter power output and receiver sensitivity levels for use in other aspects of system design.

The major assumption is the use of higher index frequency modulation with limiting demodulation. All modulations will have a predetection noise bandwidth, and some will improve on the apparent bandwidth with pre- or post-detection processing. The present intent is to work entirely with pre-detection bandwidth from which the gains or losses of alternative modulations can be entered as an adjustment.

A further major assumption is unobstructed optical propagation.

CONCLUSIONS

On a trial tabulation of the parameters described, it is found that a +0.5 dBm transmitter is required for 0 dB margin for a path length of 10 meters at 1.8 GHz.

It is not argued that one milliwatt is or is not a sufficient transmitter power, but it is a suitable reference order of magnitude. Many of the input parameters used could be differently assumed to recognize variations in system plan.

All proposals should include a power and signal level budget for the limit reach and rate circumstances.

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A further major assumption is unobstructed optical propagation.

Variables

The tabulated variables are bandwidth, transmission rate, path-length and antenna gain. Other variables are fade margin, noise figure and threshold BER, which will be treated as adjustments if other than assumed values.

Presentation Method

The required transmitter power is tabulated for various values of the variables identified above. The results are shown in three Tables for bandwidths of 10, 40 and 100 MHz. All of the values fall within about ± 20 dB of 1 milliwatt.

CALCULATION OF POWER AND LEVEL BUDGET

A number of factors go into the determination of the required transmitter power for given antennas, path description and data rate. The most basic of these are described and tabulated in the following sections.

The intention is to develop a common understanding of the input decisions and their effect on the outcome. There is no intention of making an immediate quantitative determination of transmitter power, information rates or method of modulation.

Receiver Sensitivity

The receiver sensitivity estimate contains the following elements:

Noise bandwidth:	BW = 10, 40, 100 MHz
Boltzman noise power:	$= 1.6 \times 10^{-20} * BW^{1}$
	= -98 dBm @ 10 MHz
Noise figure:	NF = 10 dB
Required S/N minimum for 10^{-6} BER:	SN = 21 dB

The factor which is more difficult to define is the minimum required S/N. Its minimum value depends on required BER, quieting obtained and the type of subcarrier modulation. **The assumption used is based on experiments with CMSK/FM and a modulation index of 3.8 times data rate.** However, there are many ways of improving BER that are not now presented including diversity and better antenna design.

The advantage of using less than possible noise figure is that the required gain in the receiver is decreased. The true Boltzman noise limited receiver could have a noise figure of 6 dB. This is a form of contingency spent as reducing the cost of the receiver.

The bandwidth adjustment is 3 dB per octave. The required signal input level at the receiver is as follows:

REQUIRED RECEIVER INPUT LEVELS VS. BANDWIDTH

Bandwidth-MHz:	10	40	100
Level-dBm:	−67	−61	−57

Antenna Gain, Cable Loss

Antenna gain is net after cable loss. This gain may be used as an offset to path loss.

For access-points, two types of antennas are considered: 1) horizontally omni-directional and quadrantally-directional (90°). For stations, two types are: 3) horizontally omni-directional and 4) fixed positioned-beam. The assumed gains are as follows:

1)	AP omni:	4 dB
2)	AP corner	10 dB
3)	STN omni:	2 dB
4)	STN aimed:	12 dB

The more directional antennas could be needed to reach higher data rates by reducing long delay multipath induced intersymbol interference.

It follows that there are four combinations with total gain as follows:

1-3 = 6 dB	1-4 = 16 dB
2-3 = 12 dB	2-4 = 22 dB

Free Space Propagation Loss

The formula for free space propagation loss (dB) between isotropic (3-axis non-directional) antennas is:

$$\alpha_0 = 92.44 + 20 \log f(\mathrm{GHz}) + 20 \log D(\mathrm{km})$$ [1]

Results are given for 1.8, 2.4 and 5.9 GHz, and for distances of 5, 10, 20 and 30 km. This table is elementary since both distance and frequency affect loss at a rate of 6 dB/octave. Referred to 1.8 GHz, the loss is 1.5 dB higher at 2.4 GHz and 10.3 dB at 5.9 GHz.

PATH LOSS VS. DISTANCE AND FREQUENCY

Path length D - meters	1.8 GHz	2.5 GHz	5.9 GHz
5	51.5	53	60.8
10	57.5	59	66.8
20	63.5	65	72.8
30	67	68.5	76.3

Transmit Level

1 milliwatt = -30 dBw = 0 dBm

Path Loss and Fade margin

It is normal for cluttered propagation through obstacles to allow 11-12 dB/octave for propagation loss after 10 meters, and to allow fade margins of 20 to 40 dB. It is now assumed that this set of conditions does not apply. It is well known that excess loss above free space is usually at least 20 dB, and it can be much higher in shadows, but these conditions will not allow high data rate transmission because of excess inter-symbol interference.

Assuming use only of unobstructed propagation paths, the fade margin assumed is 10 dB, and that is mostly for cancellation effect from short path length difference multipath. To keep within this assumption will require some artful antenna and radio design.

TABULATION OF RESULTS

The required transmitter power is built up from the receiver sensitivity as illustrated below:

1)	Rx input level (dBm) at 40 MHz bw:	-61
2)	Path loss (db) at 10 meters and 1.8 GHz:	57.5
3)	Fade margin (dB):	10
4)	Antenna gain 1-3 (dB):	-6
5)	Required transmit power (dBm):	+0.5
6)	Margin (dB):	-0.5

There is no material margin for these assumptions, but other assumptions could move it in either direction.

CONCLUSIONS

It is not argued that one milliwatt is or is not a sufficient transmitter power, but it is a suitable reference order of magnitude. Many of the input parameters used could be differently assumed to recognize variations in system plan.

All proposals should include a power and signal level budget for the limit reach and rate circumstances.

TABLE I -- REQUIRED TRANSMITTER POWER (DBM) FOR 10 MHZ BANDWIDTH

ANTENNA GAIN	F = 1.8 GHZ			F = 2.4 GHZ			F = 5.9 GHZ		
	D= 10 m	D= 20 m	D= 30 m	D= 10 m	D= 20 m	D= 30 m	D= 10 m	D= 20 m	D= 30 m
6 DB	-5.5	0.5	4.0	-4.0	2.0	5.5	3.8	9.8	13.3
12 DB	-11.5	-5.5	-2.0	-10.0	-4.0	-0.5	-2.2	3.8	7.3
16 DB	-17.5	-11.5	-8.0	-16.0	-10.0	-6.5	-8.2	-2.2	1.3
22 DB	-23.5	-17.5	-14.0	-22.0	-16.0	-12.5	-14.2	-8.2	-4.7

TABLE II -- REQUIRED TRANSMITTER POWER (DBM) FOR 40 MHZ BANDWIDTH

ANTENNA GAIN	F = 1.8 GHZ			F = 2.4 GHZ			F = 5.9 GHZ		
	D= 10 m	D= 20 m	D= 30 m	D= 10 m	D= 20 m	D= 30 m	D= 10 m	D= 20 m	D= 30 m
6 DB	0.5	6.5	10	2.0	8.0	11.5	9.8	15.8	19.3
12 DB	-5.5	0.5	4.0	-4.0	2.0	5.5	3.8	9.8	13.3
16 DB	-11.5	-5.5	-2.0	-10.0	-4.0	-0.5	-2.2	3.8	7.3
22 DB	-17.5	-11.5	-8.0	-16.0	-10.0	-6.5	-8.2	-2.2	1.3

TABLE III -- REQUIRED TRANSMITTER POWER (DBM) FOR 100 MHZ BANDWIDTH

ANTENNA GAIN	F = 1.8 GHZ			F = 2.4 GHZ			F = 5.9 GHZ		
	D= 10 m	D= 20 m	D= 30 m	D= 10 m	D= 20 m	D= 30 m	D= 10 m	D= 20 m	D= 30 m
6 DB	4.5	10.5	14.0	6.0	12.0	15.5	13.8	19.8	23.3
12 DB	+1.5	4.5	8.0	0.0	6.0	9.5	7.8	13.8	17.3
16 DB	-3.5	+1.5	2.0	-2.0	0.0	3.5	1.8	7.8	11.3
22 DB	-9.5	-3.5	-0.0	-8.0	-2.0	+1.5	-0.2	1.8	5.3

REFERENCES:

1. Reference Data for Radio Engineers - 7th Edition, SAMS, p. 34-10
2. Reference Data for Radio Engineers - 7th Edition, SAMS, p. 33-20