Radio Link Budget and Free-Space Path Loss (Friis)

Free-space path loss, received power and fade margin of a radio link from frequency, distance, transmit power, antenna gains, cable losses and receiver sensitivity.

Method: Friis free-space transmission and the first Fresnel zone

Input parameters

Unit system: SI

Parameter	Value	Unit
Frequency	2,400.0	MHz
Distance	5.0000	km
Transmit power (dBm)	20.000	
Transmit antenna gain (dBi)	14.000	
Receive antenna gain (dBi)	14.000	
Cable, connector and other losses (dB)	3.0000	
Receiver sensitivity (dBm)	-85.000	

Calculated results

Parameter	Value	Unit
Wavelength	124.91	mm
Free-space path loss (dB)	114.03	
Received power (dBm)	-69.031	
Fade margin over the sensitivity (dB)	15.969	
First Fresnel zone radius at mid-path	12.496	m

Notes for this case

- Friis free-space equation; real links add obstruction, rain, multipath and fading. Keep the first Fresnel zone at least 60 % clear of obstacles.

Formula and method

$$FSPL = 20\log_{10}\frac{4\pi d}{\lambda}, \quad P_r = P_t + G_t + G_r - L_c - FSPL, \quad r_{F1} = \sqrt{\frac{\lambda d}{4}}$$

Variables

f	Frequency	1/s
d	Distance	m
P_t	Transmit power (dBm)	-
G_t	Transmit antenna gain (dBi)	-
G_r	Receive antenna gain (dBi)	-
L_c	Cable, connector and other losses (dB)	-
S_r	Receiver sensitivity (dBm)	-
λ	Wavelength	m
$FSPL$	Free-space path loss (dB)	-
P_r	Received power (dBm)	-
M	Fade margin over the sensitivity (dB)	-
r_{F1}	First Fresnel zone radius at mid-path	m

Method and standards

Free-space radio link budget.

Assumptions and limits

- Free space, aligned antennas, far field.

References

Friis free-space transmission and the first Fresnel zone

Report details

Report reference	FCC-38KG-E9D2 (the same inputs always give the same reference)
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Calculator	Radio Link Budget and Free-Space Path Loss (Friis)
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Software release	FireCAD Calc, release of 22 November 2026
Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/electrical/electronics/link-budget-fspl

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.