LINK BUDGET

Point-to-Point RF Design Calculation

TERRESTRIAL MICROWAVE

18 GHz / 64-QAM / 28 MHz

Project	Riverlink Metro Backhaul Expansion	**Document**	LB–MW–018
Link	Rooftop Alpha – Rooftop Bravo	**Revision**	1.0
Prepared	A. Rahman, RF Planning Engineer	**Date**	02 August 2026
Checked	S. Karim, Transmission Lead	**Status**	Issued for design review

Design Decision

PASS

The clear-air link budget satisfies the project fade-margin criterion.

The calculated margin is 24.9 **dB**, providing 4.9 **dB** headroom above the required 20 dB.

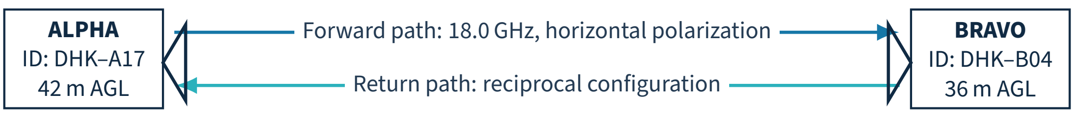
Predicted receive level
-47.1 **dBm**

EIRP	Path loss	Rx threshold	Fade margin
57.1 **dBm**	141.3 **dB**	-72 **dBm**	24.9 **dB**

Executive interpretation

The proposed 18.0 GHz hop spans 12.4 km between two rooftop sites. With 38.6 dBi antennas and 20 dBm transmitter output, the clear-air received signal is -47.1 dBm. The value remains 9.1 dB above the receiver threshold after applying the illustrative 15.8 dB rain attenuation. Final release remains conditional on path-profile clearance, licensed-frequency coordination, interference analysis, and confirmation of the radio vendor's guaranteed power and threshold data.

Network Path and Scope



Geodesic distance 12.4 km • clear line of sight required

In scope: clear-air power balance, thermal-noise threshold, fade margin, first-Fresnel-zone screening, and a planning-level rain stress case. **Out of scope:** terrain-survey certification, passive-repeater design, frequency coordination, adjacent-channel interference, XPIC discrimination, and structural loading of antenna mounts.

Input Register

Input	Symbol	Value	Unit	Basis / source
Path and radio				
Carrier frequency	f	18.0	GHz	Licensed-band channel plan
Path length	d	12.4	km	GIS endpoint coordinates
Transmit power	P_t	20.0	dBm	Vendor guaranteed output
Channel bandwidth	B	28.0	MHz	Radio configuration
Modulation	—	64-QAM	—	Adaptive-modulation profile
Terminal gains and losses				
Tx / Rx antenna gain	G_t, G_r	38.6 / 38.6	dBi	Nominal 0.6 m antennas
Tx feeder / connector loss	L_{tf}, L_{tc}	1.2 / 0.3	dB	Datasheet plus installation
Rx feeder / connector loss	L_{rf}, L_{rc}	1.2 / 0.3	dB	Datasheet plus installation
Receiver noise figure	NF	5.0	dB	Vendor maximum
Required carrier-to-noise	$(C/N)_{req}$	20.0	dB	Target BER / modulation
Implementation loss	L_i	2.5	dB	Demodulator allowance
Propagation and criteria				
Gaseous attenuation	A_g	0.7	dB	Planning estimate
Polarization mismatch	L_p	0.2	dB	Alignment allowance
Other implementation loss	L_o	1.0	dB	Radome, ageing, rounding
Required fade margin	M_{req}	20.0	dB	Project design criterion
Rain stress attenuation	A_r	15.8	dB	Planning model output
Target availability	A_t	99.95	%	Service requirement

Input discipline. Values shown are realistic sample data, not a site release. Replace them with coordinated frequencies, surveyed coordinates, manufacturer-guaranteed figures, local rain-rate data, and measured feeder lengths. Apply gains in dBi and losses as positive dB quantities; the equations provide the required signs.

Method and Governing Equations

All terms are referred to the radio connector plane. Power quantities are in dBm; gains and losses are in dB. For frequency in GHz and distance in km, the basic free-space transmission loss is

$$L_{fs} = 92.45 + 20\log_{10}(f_{\mathrm{GHz}}) + 20\log_{10}(d_{\mathrm{km}}). \tag{1}$$

The equivalent isotropically radiated power and clear-air receive level are

$$\mathrm{EIRP} = P_t - L_{tf} - L_{tc} + G_t, \tag{2}$$

$$P_r = \mathrm{EIRP} - L_{fs} - A_g - L_p - L_o + G_r - L_{rf} - L_{rc}. \tag{3}$$

The receiver noise floor, planning threshold, and fade margin are

$$N = -174 + 10\log_{10}(B_{\mathrm{Hz}}) + NF, \tag{4}$$

$$P_{th} = N + (C/N)_{req} + L_i, \tag{5}$$

$$M_f = P_r - P_{th}. \tag{6}$$

The first-Fresnel-zone radius at a point on the path is

$$r_1 = \sqrt{\frac{\lambda d_1 d_2}{d_1 + d_2}}, \tag{7}$$

with at least 60% clearance used here as a preliminary screening criterion.

Reference basis. Equation (1) follows ITU–R P.525-5. Propagation screening and availability assessment should follow ITU–R P.530-19; specific rain attenuation uses ITU–R P.838-3. Apply the editions required by the project and the national spectrum authority.

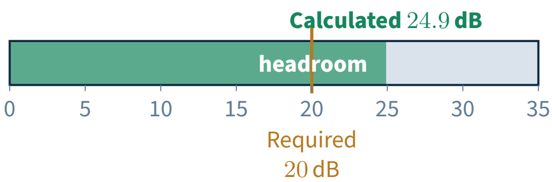
Worked Link Budget

Step	Budget item	Contribution	Running level
1	Transmitter output	$+20\,dBm$	20 dBm
2	Tx feeder and connectors	$-1.5\,dB$	18.5 dBm
3	Tx antenna gain	$+38.6\,dB$	57.1 dBm (EIRP)
4	Free-space path loss	$-139.4\,dB$	−82.3 dBm
5	Gas, polarization, and other losses	$-1.9\,dB$	−84.2 dBm
6	Rx antenna gain	$+38.6\,dB$	−45.6 dBm
7	Rx feeder and connectors	$-1.5\,dB$	−47.1 dBm
	Predicted clear-air receive level		−47.1 **dBm**
	Receiver threshold		−72 dBm
	Available fade margin		24.9 **dB**

Numerical checks

$$
\begin{aligned}
L_{fs} &= 92.45 + 20\log_{10}(18.0) + 20\log_{10}(12.4) = 139.4\,dB,\\
\mathrm{EIRP} &= 20.0 - 1.5 + 38.6 = 57.1\,dBm,\\
P_r &= 57.1 - 141.3 + 38.6 - 1.5 = -47.1\,dBm,\\
N &= -174 + 10\log_{10}(28.0\times 10^6) + 5.0 = -94.5\,dBm,\\
P_{th} &= -94.5 + 20.0 + 2.5 = -72\,dBm,\\
M_f &= (-47.1) - (-72) = 24.9\,dB.
\end{aligned}
$$

Margin visualization



Propagation and Availability Screening

Check	Calculated	Criterion	Assessment
Clear-air fade margin	24.9 dB	$\geq 20\,dB$	**PASS**
Margin surplus	4.9 dB	≥ 0 dB	**PASS**
Mid-path first Fresnel radius	7.2 m	Survey input	Screen terrain and structures
60% Fresnel clearance	4.3 m	Clear envelope	Pending path profile
Rain-stressed residual margin	9.1 dB	> 0 dB	**POSITIVE**
Target service availability	99.95 %	Contract requirement	Detailed P.530 study required

Planning stress cases

Operating case	Added loss	Receive level	Threshold headroom
Clear air	0.0 dB	-47.1 dBm	24.9 dB
Heavy-rain planning case	15.8 dB	-62.9 dBm	9.1 dB
One-end 1 dB misalignment	1.0 dB	-48.1 dBm	23.9 dB
Rain plus 1 dB misalignment	16.8 dB	-63.9 dBm	8.1 dB

The stress table is a deterministic margin test, not an availability prediction. A contractual availability figure requires local $R_{0.01}$, polarization-dependent specific attenuation, effective rain-path reduction, multipath occurrence, equipment reliability, and restoration-time assumptions. Diversity or adaptive modulation should be evaluated if the detailed model does not meet the target.

Sensitivity and Design Levers

Change from baseline	New Rx level	New margin	Engineering implication
Tx power reduced by 3 dB	-50.1 dBm	21.9 dB	Direct 3 dB loss of resilience
Each antenna gains 2 dB	-43.1 dBm	28.9 dB	4 dB total improvement
Feeder loss increases 0.5 dB per end	-48.1 dBm	23.9 dB	Control cable length and workmanship
Path length increases by 10%	-48 dBm	24.1 dB	Approximately 0.83 dB FSPL increase
Bandwidth doubles	-47.1 dBm	21.9 dB	3.01 dB more thermal noise

Preferred improvement order: verify losses and alignment first; then consider larger antennas, radio power/configuration changes, adaptive modulation, or spatial/frequency diversity. Any EIRP increase must remain within licence and regulatory limits.

Installation and Acceptance Criteria

1. Confirm coordinates, azimuths, antenna heights, and the surveyed path profile; demonstrate the required Fresnel clearance including Earth-curvature and applicable effective-Earth-radius cases.
2. Verify licensed transmit/receive channels, polarization, emission bandwidth, EIRP limit, and interference-coordination conditions.
3. Record radio model, firmware, antenna model, feeder type/length, connector count, branching losses, and vendor-guaranteed Tx/Rx values in the as-built file.
4. Align both antennas for maximum RSL. The commissioned clear-air RSL shall be within ± 2 dB of -47.1 dBm; investigate larger discrepancies.
5. Run BER/packet-loss and throughput tests in both directions, verify adaptive modulation alarms, and confirm management-system thresholds and telemetry.
6. Update the calculation with measured losses and RSL, then obtain engineering approval before the hop is accepted into service.

Assumptions, Limitations, and Approval

Item	Statement
Reciprocity	Forward and return paths are assumed to use equivalent power, gain, loss, bandwidth, and threshold values. Calculate directions separately where they differ.
Interference	The link is treated as thermal-noise limited. Co-channel and adjacent-channel interference are excluded.
Propagation	Diffraction is assumed negligible pending a terrain and obstruction profile. Gaseous and rain terms are planning inputs, not measurements.
Equipment	Threshold is derived from the entered noise figure, required C/N, and implementation loss. Substitute guaranteed vendor RSL thresholds for final design.
Accuracy	Displayed results are rounded; the calculation engine retains additional precision. Input uncertainty generally exceeds rounding error.

Prepared by	**Checked / approved by**
A. Rahman, RF Planning Engineer	S. Karim, Transmission Lead
Date: 02 August 2026	Date: ____________________

END OF CALCULATION | Document LB–MW–018 | Revision 1.0