

How to Plan Two-Way Radio Coverage: Site Survey and a Simple Link Budget

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Will the radios reach? It is the first question on every site, and it can be answered before you buy anything. A link budget adds up the gains and losses between one radio and another and shows how much signal is left. A site survey then tests the one thing the budget cannot predict: what the walls, steel and terrain actually do.

This guide shows how to build a simple link budget with a worked example, and how to survey a site with real radios.

The short answer. Power, antenna and cable are numbers you control and can calculate. Obstructions are the unknown. A link budget tells you how much loss from walls and terrain your system can tolerate, and a site survey tells you how much loss the site actually has.

The Link Budget in Six Terms

Term	What it means
Transmit power	The radio's output, expressed in dBm. 1 W is 30 dBm, 4 W is 36 dBm and 25 W is 44 dBm.
Antenna gain (dBi)	How much an antenna concentrates the signal toward the horizon. A handheld antenna is about 0 dBi or less; a base station antenna is often a few dBi.

Cable and connector loss	Signal lost between the radio and the antenna. See our coaxial cable guide for typical values.
Path loss	Signal lost travelling through space, plus everything in the way.
Receiver sensitivity	The weakest signal the receiver can use, in dBm. It is on the radio's datasheet.
Fade margin	A safety cushion for variations in signal. About 10 dB is a common starting point.

Decibels in two lines. Every 3 dB doubles or halves power, and every 10 dB is a factor of ten. In free space, doubling the distance adds about 6 dB of path loss.

Path Loss: Why VHF Reaches Farther in Open Ground

In free space, path loss grows with distance and with frequency. At the same distance, 450 MHz loses about 9.5 dB more than 150 MHz, which is one reason VHF travels farther over open ground. Figure 1 shows the numbers.

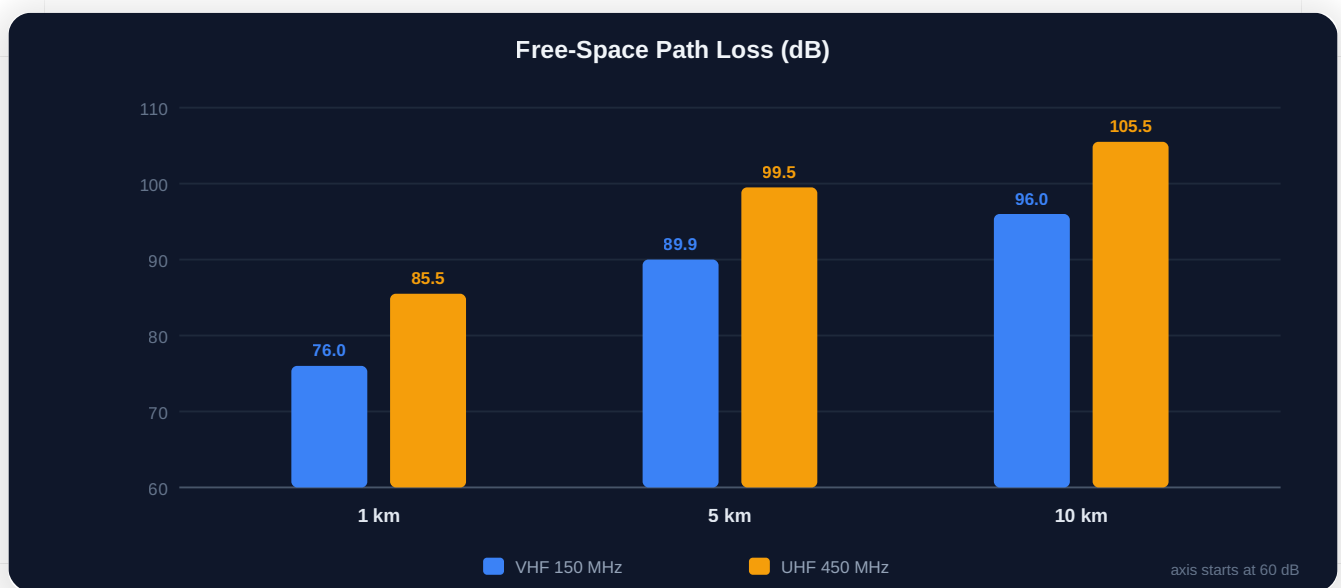


Figure 1 — Free-space path loss. UHF loses about 9.5 dB more than VHF at the same distance. Real sites add obstruction loss on top.

A Worked Example

Take a handheld talking back to a UHF base station 5 km away. The assumptions are:

- Handheld output 4 W, which is 36 dBm, with an antenna of about 0 dBi.
- Base station antenna of 5 dBi, on 25 m of cable.
- Receiver sensitivity of -116 dBm (check your radio's datasheet), plus a 10 dB fade margin, so the signal must arrive at -106 dBm or better.
- Free-space path loss at 450 MHz and 5 km of 99.5 dB.

The signal at the base receiver is $36 + 0 + 5 - \text{cable loss} - \text{path loss}$. Working backwards from -106 dBm gives the total path loss the link can tolerate. Subtracting the 99.5 dB of free-space loss leaves the amount available for obstructions:

Cable (25 m, UHF)	Cable loss	Path loss the link allows	Left for obstructions at 5 km
LMR-240	4.3 dB	142.7 dB	43.2 dB
LMR-400	2.2 dB	144.8 dB	45.3 dB
LMR-600	1.4 dB	145.6 dB	46.1 dB

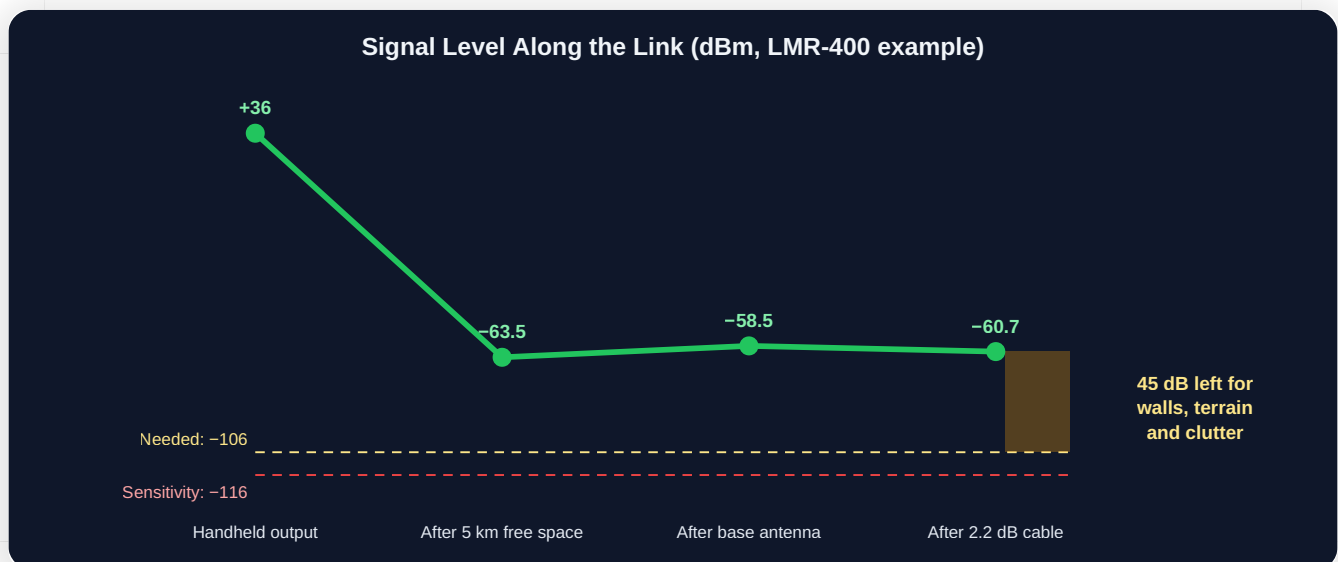


Figure 2 — The signal falls to -60.7 dBm at the base receiver in free space. The gap down to the -106 dBm target is the loss the site can still take.

The result is a budget, not a promise. It says this link can tolerate roughly 45 dB of obstruction loss at 5 km. A brick wall, a steel structure or a hill can use up a large part of that, and each one has to

be measured. Notice too what the cable did: moving from LMR-240 to LMR-400 gave back 2.1 dB, which is 2.1 dB more room for obstructions at no cost in radio power. The free-space result alone would allow hundreds of kilometres, which is why real coverage is limited by obstructions and the radio horizon rather than by the budget.

How to Run a Site Survey

1. **Mark the area and the hard spots.** List the far corners, basements, stairwells, lifts and plant rooms where coverage matters most.
2. **Use the real equipment.** Test with the radios and band you plan to buy, ideally with the actual antenna and cable.
3. **Put the base or repeater where it will go,** at the planned antenna height, not on a desk.
4. **Walk the site.** At each point make a test call, and note the signal level if your radios show it, or the voice quality if they do not.
5. **Test the worst cases:** closed doors, busy areas and the lowest floors.
6. **Adjust and repeat.** Raise the antenna, move the site, shorten or upgrade the cable, or add a repeater, then test again.

If the survey shows gaps that power and cable cannot fix, a repeater is usually the answer. See our guide to [repeaters vs direct mode](#). Which band you choose affects both path loss and building penetration, so read [VHF vs UHF](#) too, and install the antenna correctly using our [antenna installation guide](#).

Frequently Asked Questions

+ What is a link budget?

It is a running total of gains and losses from the transmitter to the receiver: transmit power, antenna gains, cable loss and path loss. If the signal that arrives is above the receiver's sensitivity plus a safety margin, the link should work.

+ How much fade margin should I allow?

About 10 dB is a common starting point. Use more for critical links or sites with a lot of movement and clutter, and let survey results guide you.

+ Does a higher-gain antenna always help?

No. Higher gain squeezes the signal into a flatter beam toward the horizon. That helps over open ground, but it can leave nearby upper or lower floors and hills poorly covered. For a base station serving a multi-storey building, a moderate gain is often better.

+ Why does the calculation show hundreds of kilometres but my site only reaches a few?

Because free-space loss ignores walls, terrain and the curve of the earth. The budget shows how much obstruction loss you can afford. The site decides how much you actually get.

Radios, Cable and Connectors for a Reliable System

Bravosatcom supplies two-way radios from Motorola, ICOM and Kenwood, with the LMR cable and connectors to build a system that performs.

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