Episode Book

EPISODE #5733

Why Your Raspberry Pi's Wi-Fi Keeps Dropping

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SYNOPSIS

Your Raspberry Pi's built-in Wi-Fi isn't badly designed — in an anechoic chamber it measures above -2 dB, roughly 70% efficiency. So why does the link fall apart in the real world? This episode digs into the physics and field data behind unstable SBC connectivity: PCB trace antennas that are narrowband and placement-sensitive, USB 3.0 broadband noise that can raise the 2.4 GHz noise floor by up to 25 dB, and why the adapter you should buy is the best-supported one, not the fastest. We also cover what "high gain antenna" claims actually mean, why chipset choice has narrowed to three suppliers, and how USB bus power budgets cause drops that look exactly like Wi-Fi problems.

TRANSCRIPT



Corn

What makes a Wi-Fi adapter good? If your answer was "the speed rating," you're answering the wrong question, and it's the answer almost everyone gives.



Herman

Almost everybody.



Corn

Daniel wrote in with a whole thing about this. He's got a Raspberry Pi and SBC use case, the IoT end of the house, where the goal isn't throughput at all, it's a connection that just stays up. And he says the radios built into these boards are weak enough that in his experience the link becomes unusable. So he wants thoughts for the buyer picking up a USB Wi-Fi dongle for one purpose only. Stable, reliable connectivity.



Herman

One purpose.



Corn

Which he points out really makes it a question about antennas and antenna placement relative to the device. Then the specific asks. Why do the built-in radios on Pis and SBCs perform so poorly despite what the specs suggest. What actually matters when stability is the only criterion. How much do antennas and their placement really affect things. What do claims like "high gain antenna" actually mean. How do the form factors stack up, the tiny stub, the six-inch antenna, the cabled external one. And what would a winning spec sheet look like for an adapter optimized purely for stability over the LAN.



Corn

He's got a suspicion underneath it, too. He thinks this is really a question about antennas and antenna placement, and he wants to know what differentiates these products. So let's start with why the radio that's already on the board is so often the problem.



Herman

Here's the reframe, and it's going to sound wrong for a minute. The three things that decide whether this works, throughput, standard version, stream count, none of them are on your side. The metric that matters is link stability, and stability is an RF problem and a systems problem. It is not a radio-spec problem.



Corn

Say more, because "buy the newer standard" is what everybody does.



Herman

Newer standards are about moving more bits when everything is already good. Wi-Fi 7 is a throughput story. But a dongle that negotiates 802.11ac and holds minus forty-five dBm for six months is more useful to you than one that negotiates the latest thing and drops every time the fridge compressor kicks on. Stability comes from three variables that don't appear on any spec sheet. Antenna placement and physical separation. USB 3.0 interference. And driver quality.



Corn

Those are three sentences that a marketing department would rather you never read.



Herman

Right, and there's a resource problem here that's worth naming. The closest thing to a real buying guide for this, anywhere, is a GitHub project. It's morrownr slash USB Wi-Fi, it's got about four and a half thousand stars, roughly forty-seven thousand views a month as of last month. It maintains tested adapter lists, a short list, a long FAQ. That's the reference.



Corn

A hobbyist repo as the de facto standard.



Herman

There is no published spec sheet for a stability-optimized USB Wi-Fi adapter. Not from the vendors, not from the community. What we're going to build today is synthesized from physics and field data, it isn't quoted from one document. And that absence is itself the story.



Corn

To understand why the dongle matters, you first have to understand why the radio already on the Pi is so disappointing. And the answer starts with a surprise.



Herman

Start with what the antenna actually is, because the assumption is that it's cheap garbage. Since roughly the Pi 3 era, Raspberry Pi boards use a PCB trace antenna. Not a chip antenna. That's a cost decision on the bill of materials, a printed copper trace instead of a component.



Corn

A trace.



Herman

And there's a teardown analysis of the Pi Zero W and the Pi 4 antenna that's worth reading. It's a wideband dipole, heavily shorted with inductance, rematched to center with series and shunt capacitors. Cser1 at one point two picofarads, Cser2 at two picofarads, Cshunt at two point six picofarads. Those are the actual matching values.



Corn

So somebody sat down and did the math.



Herman

And here's the part people get wrong. In an anechoic chamber, peak efficiency measures above minus two dB. That's roughly seventy percent. The analyst's own words, "a pretty good antenna."



Corn

So the design isn't the problem.



Herman

But efficiency falls off rapidly. Because of that heavily shorted nature, it's a narrowband design, and the impedance moves fast across the band. It's tuned beautifully at the center and it degrades as you leave it. And Raspberry Pi's own whitepaper, RP dash nine seven six three, acknowledges it. Board computers include only an on-board PCB antenna. External whip antennas are only offered on the Compute Module range.



Corn

Which is the admission that the on-board one is a compromise.



Herman

A cost compromise, not an engineering failure. The failure is environmental. There's a post on the Core Electronics forum from December twenty twenty-two that says it about as plainly as it can be said. The antenna is embedded in the PCB, the design is clever, but overall performance is constrained by the location of the device and the surrounding materials that absorb and reflect signal.



Corn

So the antenna's fine. Where it lives is not.



Herman

And there's an anecdotal layer on top. Pi 5 users on the Raspberry Pi forums reporting onboard Wi-Fi performing worse than Pi 4 in some setups. One user ordered a second Pi 5 thinking the first was defective. Both exhibited the same poor performance. Fair warning, that's forum-reported, not confirmed by a primary source, but the report is specific enough to take seriously.



Corn

Two boards, same behavior, and the user's conclusion was that the hardware was broken twice. That's what bad placement does to you. It makes you blame the wrong object.



Herman

Now the hidden killer. USB 3.0 interference. This is where it stops being about the antenna entirely.



Corn

This is the one that made me sit up.



Herman

Intel published a white paper in twenty twelve on USB 3.0 radio frequency interference with 2.4 gigahertz devices. Document three two seven two one six. And the core fact is that USB 3.0's five gigabit data spectrum is broadband. It ranges from DC to five gigahertz. There's high noise right in the two point four to two point five gigahertz range, which is exactly where most IoT Wi-Fi lives.



Corn

That's not a coincidence, that's an overlap.



Herman

It's the worst possible overlap. And the measured numbers are dramatic. An external USB 3.0 hard drive raised the 2.4 gigahertz noise floor by nearly twenty dB. The noise from a notebook's USB 3.0 receptacle connector raised it by about twenty-five dB.



Corn

Twenty-five dB. That's not interference, that's a jammer.



Herman

Effectively, yes. Shield a USB 3.0 peripheral fully and you reduce radiated noise by about twelve dB. Improve the connector shielding and you drop it by at least ten. So the fix exists, but it has to be designed in.



Corn

Which most cheap hubs and cables don't do.



Herman

And here's the test from that paper that should be framed and hung on a wall. A wireless dongle placed on the opposite side of the laptop, connected via a USB 2 extension cable, worked fine at two feet, three feet, and five feet. A dongle stacked vertically above the USB 3.0 port got "No Response" at every distance.



Corn

At every distance.



Herman

Every single one. Same radio, same laptop, same room. The only variable was where the antenna physically sat relative to the USB 3.0 connector. Intel's own conclusion is in the paper. Placement of the wireless antenna should be located as far away as possible from a USB 3.0 connector and or device.



Corn

So to bring it back to Daniel's Pi. The board's antenna is fine, it measures at roughly seventy percent efficiency, and it's sitting millimeters from the PCB, usually inside a metal or absorbing case, and frequently right next to the USB 3.0 ports and whatever cable is plugged into them.



Herman

Which means the failure is environmental. And that has a real consequence for how you spend money. The fix may not be a new adapter at all. The fix may be separation.



Corn

That's the kind of conclusion that ruins a shopping trip.



Herman

So if the onboard radio's failure is environmental, what actually determines whether an external adapter succeeds? That's where the buying criteria get counterintuitive. Number one is not the radio.



Corn

Say it.



Herman

It's the driver. morrownr's golden rules read like a set of commandments. Prefer in-kernel drivers, plug and play, standards compliant, maintained upstream. Avoid multi-state adapters, the ones that present themselves as a CD-ROM or a flash drive first so they can load a Windows driver. And avoid multi-function adapters that combine Wi-Fi and Bluetooth.



Corn

Why the Bluetooth one? That sounds convenient.



Herman

His line is that Bluetooth will likely limit the Wi-Fi to USB 2 speeds. If you need Bluetooth capability, go get a separate Bluetooth adapter. Combining them sounds like a win and isn't.



Corn

The convenience tax.



Herman

And the chipset landscape is much narrower than buyers assume. Only three companies still supply USB Wi-Fi chipsets. MediaTek, AIC Semiconductor, and Realtek. Intel and Qualcomm-Atheros no longer supply modern USB-capable chipsets.



Corn

Intel, who wrote the white paper about the interference.



Herman

Intel, who left the USB dongle business. And for Linux, morrownr's recommendation is MediaTek. His assessment of Realtek is blunt enough to quote. "Am I a fan of how the Realtek USB team supports the Linux community? No."



Corn

That's a man choosing his words carefully by not choosing them.



Herman

The implication is what matters for a stability buyer. A worse radio with a good in-kernel driver can be the more reliable choice than a higher-spec adapter running an out-of-kernel driver. You are not buying the best radio, you are buying the best-supported one.



Corn

Second criterion. Power.



Herman

This almost never appears in marketing. On an SBC, the USB bus has a budget. morrownr's performance comparison lists heavy-load power draw. Alfa AWUS036ACS at two hundred seventy milliamps. The AWUS036ACHM and AWUS036ACM at three hundred eighty. The EDUP EP dash AC1605GS at five hundred twenty. And the Alfa AWUS036ACH at eight hundred milliamps.



Corn

Eight hundred milliamps on a Pi's USB bus.



Herman

Can cause brownouts and drops, especially with anything else drawing off the same bus. He uses the AWUS036ACM with a Pi 4B as an access point specifically because of this. His words, "the low power requirement makes it a very good match for Raspberry Pi hardware." That's a stability decision disguised as a spec choice.



Corn

What's the actual power budget on something like a Pi 4?



Herman

It's tight. The total across all USB ports is well under what a desktop provides, so a single adapter pulling eight hundred milliamps can be most of what you have before anything else is plugged in. Solder a keyboard or a bus-powered drive alongside it and you're asking for drops that look exactly like Wi-Fi problems. Which is how people end up replacing a perfectly good adapter.



Corn

Now the antenna physics, because this is where Daniel's suspicion about "high gain" claims gets answered.



Herman

It gets answered hard. Dan's Data, which is a long-running Australian tech site, put it this way about add-on Wi-Fi antennas. "Most add-on WiFi antennas are impossible. They can't exist. What's written on the box is contrary to physical laws."



Corn

That's not a hedge.



Herman

A three dBi antenna has a three dB, or twofold, gain advantage over a theoretical perfect isotropic radiator. And that theoretical radiator would need to emit twice the energy you put in. So a "gain" of three dBi is already at the edge of what physics allows without directing the energy somewhere.



Corn

So where does the gain come from?



Herman

From not radiating in all directions. That's the trick. The higher the gain of an omnidirectional add-on antenna, the wider the cones above and below the axis where it doesn't work well, or even at all.



Corn

The doughnut.



Herman

Core Electronics puts it well. As antenna gain increases, the doughnut flattens out. More signal pushed horizontally, less vertically. Which is great if your access point is on the same floor and terrible if it's upstairs. The gain you bought is signal you removed from somewhere else.



Corn

And the "high gain" buyer is usually putting the access point upstairs.



Herman

Usually, yes. RFI in the antenna business has a line about this. The laws of physics cannot be defeated, and without capture area there is simply no way to increase antenna gain. IoT UK goes further and calls antenna gain "one of the most abused marketing terms in the industry."



Corn

So what's a real number?



Herman

A standard dipole, the rubber duck on the side of most routers, is the two point one four dBi reference. And there's a common confusion between dBi and dBd, two different references, which lets manufacturers inflate numbers. For a fixed indoor LAN link, a modest two to five dBi antenna may serve you better than a nine dBi one, because the



Herman (continued)

nine dBi one is carving nulls above and below it.



Corn

That's the exact opposite of what the packaging implies.



Herman

Completely opposite. Because the correct answer for your room depends on where the access point is, and the box doesn't know where your access point is.



Corn

Now the form factors, because Daniel asked specifically.



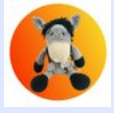
Herman

And here's the insight that reframes the whole purchase. Core Electronics makes the decisive RF point. With a USB extension cable, you can use several meters of cable to locate the antenna in the best possible position without incurring any RF signal loss, as you would with an antenna connected by RF coax cable.



Corn

Why is that true?



Herman

Because the signal is still digital in that cable. You're extending the USB bus, not the RF path. Once it becomes RF, at the antenna, coax losses matter enormously. In the USB domain, you're just moving the radio to a better address.



Corn

So the cabled form factor's real advantage is not the antenna. It's the separation.



Herman

The fancy-looking antenna on the end of a cabled adapter is almost the least important part of it. What you're buying is a way to put distance between the radio and the Pi's USB 3.0 ports and its metal case. That's the whole game.



Corn

Which loops right back to the Intel test.



Herman

Straight back to it. And morrownr's practical guidance on this is useful. Extension cables with cradles can be very useful, they let you position the adapter for best performance. But with a warning attached. Some adapters won't work with some extension cables and cradles, and the only way to know is trial and error.



Corn

Trial and error. Honest, at least.



Herman

He also covers right-angle USB adapters. Those can be very handy, especially on a Raspberry Pi or other small systems with horizontal USB ports, and he's never seen a compatibility problem with them. Which is a cheap way to change where the adapter points.



Corn

What does the placement guidance actually say?



Herman

Place antennas as high as possible above the ground, at least two to three meters, and try to get clear line of sight, accounting for the Fresnel zone, which is the football-shaped volume around the direct path where the signal wants to spread. And the Core Electronics line that pulls it together. Typical Wi-Fi stick antennas offer gains of a few dB, but the placement of the antenna can easily affect the end to end signal path by several tens of dBs.



Corn

Tens.



Herman

Tens. You are choosing between a few dB of antenna gain and tens of dB of placement. The antenna is the rounding error.



Corn

Let's put real numbers to the form factors, because Daniel asked how they differ in reliability.



Herman

There's a test from morrownr dated May thirty-first twenty twenty-one. Forty-five feet, through three walls, channel one forty-nine at eighty megahertz. Link quality out of a hundred, and signal level. The Alfa AWUS036ACHM, mt7610u chipset, single antenna, top of the list at ninety-three out of a hundred at minus forty-five dBm. The Alfa AWUS036ACH, rtl8812au, two antennas, ninety-one at minus forty-six. The EDUP EP-AC1605GS at eighty-four, minus fifty-one. The Alfa AWUS036ACM at seventy-nine, minus fifty-five. And the Netgear A6210 at the bottom, sixty-four out of a hundred at minus sixty-five dBm.



Corn

And the Netgear is the portable-looking one.



Herman

His note is that it likely appears at the end of the list because of its design. It's designed for portability, not long range. The tiny stub form factor is a portability product. It's not cheating you, it's doing a different job.



Corn

So that's the answer to the form-factor question. The stub isn't a worse version of the cabled one. It's optimized for a different thing entirely.



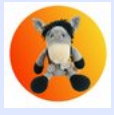
Herman

And here's the stability metric that ties all of it together, which is what I'd want Daniel to take away. morrownr's FAQ warns that a signal level weaker than minus fifty-two dBm may be at a level that can adversely affect jitter levels, and jitter disrupts the smooth flow of data.



Corn

Minus fifty-two.



Herman

He advises checking signal level before anything else. Not throughput, not link speed. Signal level. Because jitter is what makes an IoT link feel broken. The packets still arrive, they just arrive late, and anything that cares about timing falls apart.



Corn

So the number to chase is dBm, and the target is better than minus fifty-two.



Herman

Better than minus fifty-two with margin, ideally. And notice the test above. Only two of those five adapters cleared that bar in that particular situation. The others didn't, and no amount of throughput would have saved them.



Corn

So build the winning spec sheet. Daniel asked for it explicitly.



Herman

It doesn't exist as a published document, so here's the synthesized version. One. In-kernel Linux driver, ideally mediaTek chipset, because driver quality determines stability more than radio specs. Two. Single-function. Not Wi-Fi and Bluetooth combined. Three. Not a multi-state adapter that pretends to be a CD-ROM first. Four. Power draw in the two hundred seventy to three hundred eighty milliamp range, for SBC compatibility. Five. A cabled or cradle form factor, so you can physically separate the radio from the Pi's USB 3.0 ports and its case. Six. Modest antenna gain, two to five dBi, matched to where the access point actually sits, not the highest number on the shelf. And seven, a documented community track record.



Corn

Which is the morrownr short list criteria.



Herman

In-kernel driver, documented track record, currently purchasable. Those are his three tests.



Corn

So read your list back to me and notice what it's mostly made of.



Herman

It's mostly things the adapter doesn't do. It doesn't combine functions. It doesn't draw too much power. It doesn't depend on an out-of-kernel driver. It doesn't trap the antenna against the Pi's USB 3.0 ports. The antenna is almost the last item.



Corn

The best spec sheet for this use case is a list of absences.



Herman

And the physical joke underneath it is that 2.4 gigahertz has a half-wavelength of about six centimeters. Which is roughly the length of a Pi Zero. An antenna that size is sitting inside a device that small, next to a USB 3.0 port, inside a case, on a shelf, next to a wall.



Corn

Every one of those is doing damage.



Herman

Every one of them.



Hilbert

That all tracks. But the cable is what matters.



Herman

Go on.



Hilbert

I spent a couple of years doing installs where we were mounting small radios in bad places. Ceiling voids, plant rooms, back of a shop counter. And the thing I learned is that a long USB cable is the cheapest antenna you can buy. I used to keep a roll of the cheapest USB 2 extensions I could find in the van, specifically because they were long and thin and unshielded, which is exactly what you want for this. You tape the dongle to the top of a doorframe or a shelf bracket and run the cable back to the box. I fixed more flaky links that way than with any adapter swap I ever did.



Corn

Cheapest possible cable.



Hilbert

It was about the length, not the quality. I was chasing one fault for three weeks. Device in a back office, held a link fine all day, and every time somebody walked past the doorway it dropped. I swapped three different adapters through it. Never the radio. It was the antenna sitting against a steel door frame and a USB 3 port, and once I got it up on the top of the frame on a long cable, it never dropped again.



Herman

So you're saying the whole adapter question is downstream of that.



Hilbert

For most people, yes. The cheapest adapter on a long cable in the right place will beat the best adapter jammed into the port every single time. You two spent the episode building a spec sheet. I'd say the first line of the spec sheet should be a longer cable, and the second line should be somewhere better to put it.



Corn

And the cradles.



Hilbert

The cradles are the thing. Not the right-angle adapters, those are fine, I never had a problem with them. It's the cradles that fall apart. The plastic ones break at the pivot after a couple of years, and then the dongle hangs off the cable by its own weight. Get a metal one or skip it entirely and use tape, like I said.



Herman

Tape.



Hilbert

PVC tape, the good stuff, doesn't go gummy in a hot ceiling void. That's the whole trick. Tape the antenna to the doorframe, run the cable back, done. Then you can stop arguing about which adapter.



Corn

The winning spec sheet is a piece of tape and a longer cable.



Hilbert

That's the honest version.



Corn

That image of taping a dongle to a doorframe is probably the most honest summary of this whole topic. A cable and a better place to put it.



Herman

It makes a point that the research can't. We can establish the physics. Intel's paper tells you why the interference happens. The community tells you which adapters are supported. None of that tells you that the answer is often a roll of cheap cable and some tape.



Corn

Before we go. The cutting-room floor. One thing from the research that didn't fit.



Herman

The fresnel zone. The football-shaped volume around the direct line between two antennas. And what's striking is how small the practical margin is indoors. You can have clean line of sight, you can see the access point, and still lose signal, because something is intruding into the volume around that line, not the line itself. A door, a person, a filing cabinet. It's the reason a link that looks perfect on a diagram fails in a real room.



Corn

The honest open question is why the whole market still sells on speed and gain numbers. If the fix is separation rather than a new adapter, what would it take for a vendor to market a stability-first adapter honestly? "This one is boring and it will not drop." Good luck with that on a box.



Herman

The problem gets worse, not better. As SBCs get more capable, USB 3.0 becomes standard on more of them, and the interference problem scales with adoption. Which makes the community's trial-and-error knowledge base more valuable over time, not less.



Corn

Leave it here. The best Wi-Fi adapter for a Raspberry Pi may be the one you already own, plus a long cable and a better place to put it.



Herman

Thanks as always to Hilbert Flumingtop, our producer.



Corn

This has been My Weird Prompts. If you've got a prompt, send it our way. Email us at show at my weird prompts dot com. We'll be back soon.