Making a WiFi Dipole Antenna

for carrying RF outside shielded enclosure

Problem

The Grizzl-E Charger has a robust aluminum enclosure. This is great for durability, but lousy for allowing the smart version of the Charger to communicate via WiFi with the outside world; the metal acts as a good shield for the RF, and I suspect that most of the signal seen by the outside world gets there by leaking out through the power cables. Testing with and without the cover installed showed an average of 25 dB difference in signal strength.

Solution

While the power cables are able to bring some of the WiFi signal out, they are not optimized or tuned to be efficient at WiFi frequencies. However, a short section of coax, with a dipole antenna at both ends and intentionally sized to resonate at 2.4 Ghz will perform much better at capturing the RF inside the box and re-radiating it outside the box.

Here are instructions for making such an antenna and installing it in the Grizzl-E Charger. Though the modifications are minor (adding one hole in the enclosure), please note that you are responsible for your own safety and any damage you might do to the charger. Ensure you do all work with the power disconnected to the Charger.

Preparing the Antenna

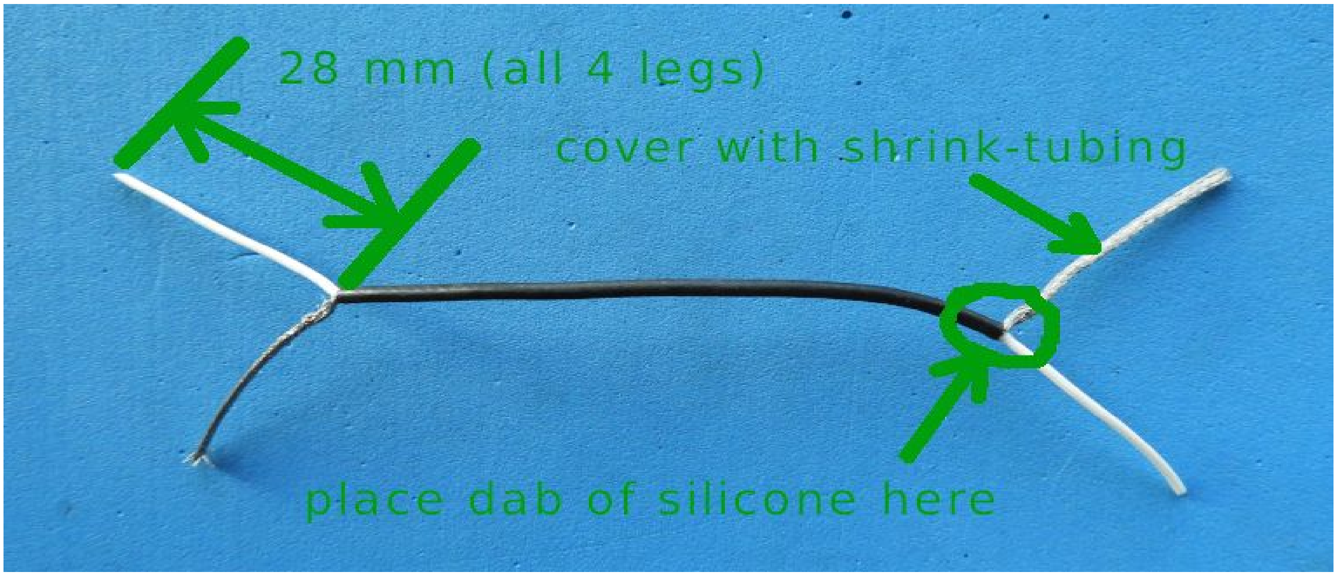
Obtain a piece of coax cable, approximately 18 cm long. Preferably it should be 50-ohm impedance coax, but 75-ohm (often used for cable TV applications) will also work. Since we are dealing with very low RF power, the diameter of the coax is unimportant, except that it has to fit through the hole you will be drilling in the enclosure. RG-174 coax is what I used.

Strip the outer layer of insulation from each end, to expose about 40 mm of the shield (braided wire) at each end. The exact distance is not critical, since you will trim the coax later.

Separate the shield and the insulated centre conductor from each other. One way is to use tweezers to separate the braid strands near where they are first exposed, and then pull the centre conductor through. Another way is to ‘comb’ out the braid into its individual strands to expose the centre conductor, and then re-twist the braid strands back into one wire.

Trim the lengths of the exposed braid, and centre conductor, to 28 mm at both ends.

Your coax should now look like this (outer and inner insulation colours may vary):



For weather-proofing:

- Put a dab of silicone (or hot-melt glue, which may not be as weather resistant) at the two junctions of the braid and centre conductor.
- Slide a piece of heat-shrink tubing over the braid at each end and shrink it.

Preparing the Enclosure

Disconnect power to the charger.

Remove the front cover.

Locate the blind hole (one of three) in the enclosure just above the tops of the circuit boards and closest to the ESP32 module. See photo in following section – green arrow.

Drill out the hole to make a passage to the exterior, wide enough for your antenna to pass through. Be careful not to allow metal shavings from the drilling operation to fall onto or get stuck on the circuit boards. Making a cardboard shield to contain the shavings, and orienting the enclosure so gravity pulls the shavings away will help.

Installing the Antenna

Push the antenna about half-way through the new hole you made.

Position the legs such that the centre conductor can be taped to the edge of the ESP32 module's WiFi Antenna, and the braid leg can be taped to the enclosure. You do not want to make a conductive connection with the antenna, nor permanently modify the ESP32 – instead, you are merely placing the centre coax conductor in the near-field of the ESP32 antenna. I used kapton tape, but any other non-conductive tape whose adhesive doesn't soften too much over time is fine. Some PVC electrical tapes unfortunately tend to get gummy with heat and time, so might not be as satisfactory. See following photo.

Fill the enclosure’s antenna hole with silicone or some other sealant to keep water and dust out.

Position the antenna legs protruding from the enclosure such that at least the centre conductor is not directly up against any metal. Here is the exterior view:

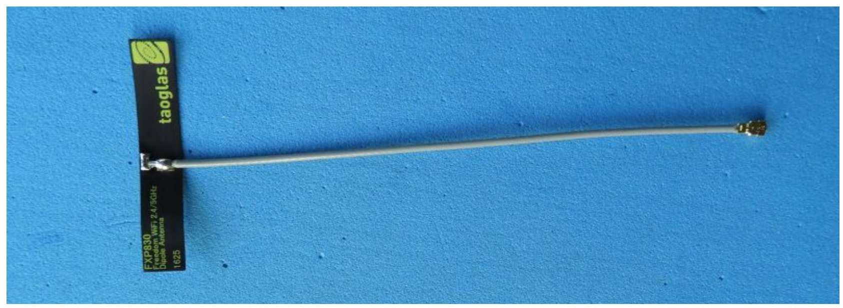
Replace the cover on the Charger and plug it in.

Testing

Use your WiFi router's diagnostics, or a WiFi signal strength app on a phone, to check the signal strength of the Charger. It should be noticeably stronger than before this modification. You can experiment with the orientation of the antenna legs to obtain the optimum position. On my unit, I noticed about a 20dB improvement in signal strength with the antenna, and the cover installed. This brought it to just a few dB below the signal strength observed with the Charger's cover removed and no added antenna.

Comments and Further Thoughts

An alternative to making your own coax antenna is to use a commercial 'patch' style antenna, such as shown here (Digikey part 931-1127-ND). You would need to buy two of these, stick one antenna outside and the other inside the box, and then join the two cables by either soldering or a connector.



Another alternative design approach is to solder the inside end of the coax directly to the ESP32 module's antenna. This involves carefully scraping the soldermask layer from the ESP32 PCB at the point where the copper traces form the antenna feed and the antenna ground, and soldering the coax centre conductor and shield to the feed and ground, respectively. This approach will give a higher signal strength than merely coupling to the near-field of the ESP32's antenna, but has the disadvantage that it can damage the ESP32's RF block if not done correctly.

Lots of variables will affect the efficiency of an antenna, such as coax type, angles of legs, and proximity to adjacent metal. The position and angle of the legs can be tweaked while observing the WiFi signal strength. Another of the variables that can be tweaked is the length of the legs, which affects the resonant frequency of the antenna. The value given in these instructions (28 mm) worked well for my particular installation, but if you wish to further explore this, then you can initially cut the legs a bit longer (say 32 mm) and then trim about 1mm off at a time while observing the signal strength. It will likely improve as you approach the optimum length, and the the signal strength will fall off as the legs become too short. Take note of the length that performed best, and then build a second antenna using the same materials but with the best-observed length.

Good luck and have fun!
Bjarne