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I'm submitting the following article I recently had published in QST magazine to indicate, yes, there is a problem with unintended radiators. Following publication of this article, I was immediately bombarded with request for help from hams and two industrial concerns; both of whom make variable speed motors.

This should not be a surprise to anyone, with the state of the art for energy efficiency being a pulse width modulated control. The high rise times of the wave form are disastrous to HF.

A Tale of Two Air Conditioners

Twisting wire pairs and installing ferrites helps reduce RFI.

Robert C. Lee, W0GXA

This is a tale of two air conditioners — one at my home in Iowa and the other at PJ2T on Curaçao. Both are relatively new, high-efficiency units, and both had various undesirable RFI characteristics on the 20 meter band. I want to share some practical techniques you can apply to your furnace or air conditioner to eliminate RFI.

Air Source Heat Pump

I noticed clusters of birdies of varying intensity up to S-9, spaced 18 kHz apart in the 20 meter band. Very weak RFI also appeared on 15 and 10 meters. I had installed a new propane furnace with a high-efficiency air source heat pump the prior fall. The RFI was present whenever the heat pump was operating. I first surveyed the outdoor heat exchanger unit, diagrammed in Figure 1. Power enters through a contactor and then to a pulse width modulated (PWM) controller that controls the speed of the fan motor. Motor speed commands are set via two wires coming from the control board. A cable with a ground wire runs from the PWM controller to the fan motor with one break at a bulkhead connector. I had read about high-efficiency units with multiple speed fans generating RFI because of PWM controllers and inverters, so I asked for help on ham radio e-mail lists. Ken Cechura, KC9UMR, responded.

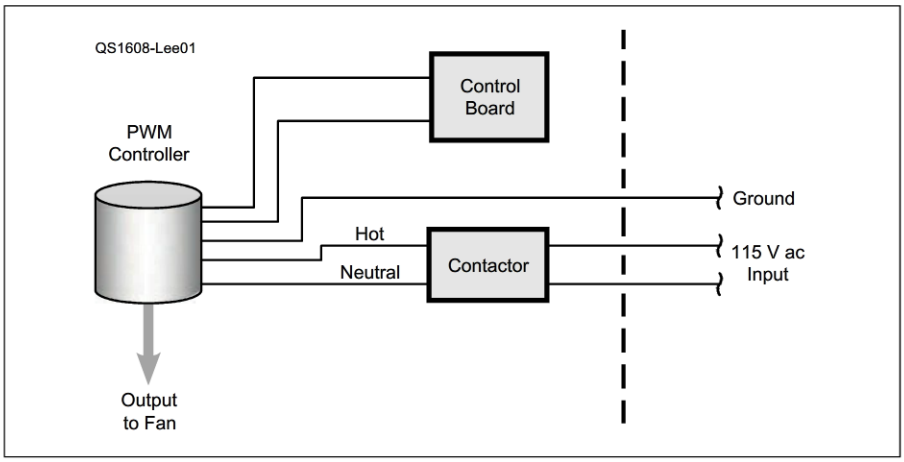

Figure 1 — Block diagram of a heat exchanger fan motor control.

Searching for RFI

Ken suggested several points to consider in searching for problems.

1) A break in a shield greater than 1/20 of a wavelength is a possible source of noise, but not a probable cause. They are typically not worth chasing down until other methods have proved unsuccessful.

2) Signals should be run along with their return lines as wire pairs. A positive motor power wire should be run along with the negative motor power wire. A positive control wire should be run with the negative control wire.

3) Twisting wire pairs provides significant levels of containment and RFI rejection. One twist every 1 to 2 inches is good below 30 MHz.

4) Ferrites can provide a level of attenuation depending on whether you choose a toroid or clip-on beads. For best results, wrap several turns of wire around the core. Toroids may yield better results because of the continuity of the material, whereas clip-on beads have a split that can affect their performance. Clip-on ferrites can be considered a troubleshooting measure. Snap one on to a cable harness, and observe the effects. If positive changes are noted, then look for ways to install a toroid of the same or a better material.

Figure 2 — Interior of the PWM controller shows installed ferrites. [Bob Lee, W0GXA, photo]

5) At HF, use ferrite mixes #31 or #43. For lower frequency, 160 and 80 meters, use mix #75.

6) Full shielding, enclosing the whole system in a grounded Faraday cage, might be necessary for frequencies above 30 MHz. Shielding, however, requires detailed attention to the entire housing, or wrapping braid over all cables. This is not a quick field fix.

I fashioned an RF sniffer out of a short piece of coax with a few inches of center conductor protruding, and attached it to my HF-capable handheld radio. I used the sniffer along the power path from input to the unit, through the PWM controller, and finally out to the fan motor. Most of the noise was from the cable bundle entering the controller. The hot spot was the PWM controller for the fan motor.

Shielding

Shielding is effective only when the source and any connected emitters can be enclosed. To be effective, shielding would be needed on the wires, with bonding to the

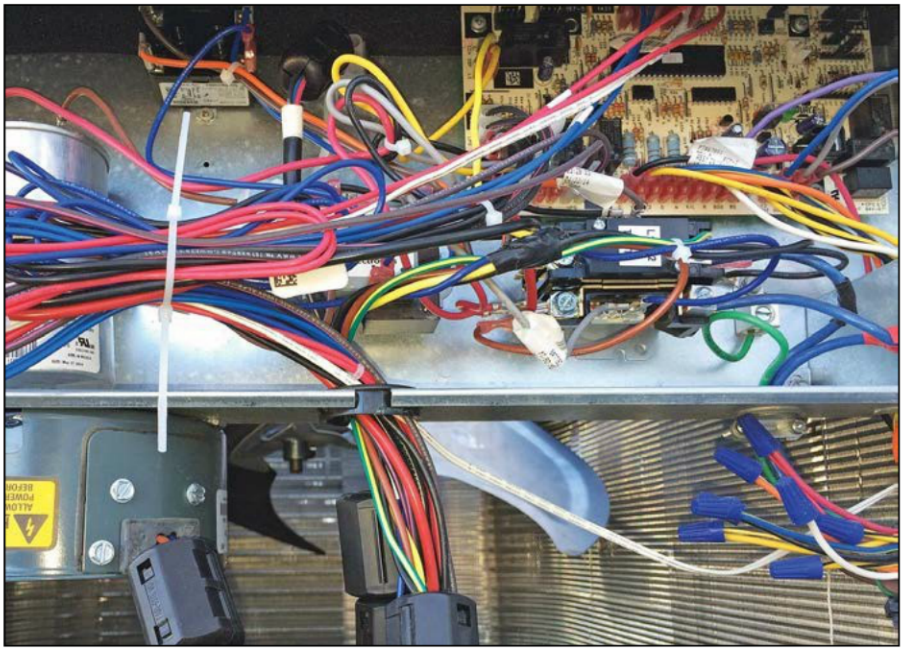

Figure 3 — Wiring harness with ferrites installed. [Bob Lee, W0GXA, photo]

Figure 4 — With tie wraps removed, twist the wire bundles tightly and install ferrite beads. [Bob Lee, W0GXA, photo]

motor and controller housings. However, a shield over just the wire harness is not practical, which means the entire air conditioning housing would have needed to be well shielded. Because of the complexity of shielding, the wire twisting was much more practical for this application.

Solutions in Iowa

At my home in Iowa, I added clip-on beads to both the output and input cables. This provided limited success. An S-9 signal was attenuated to S-5 to 6. Clearly, more attention was needed.

Twisting wire pairs is likely the single most important thing you can do to reduce radiation or minimize susceptibility.

I focused next on the input harness. When I disassembled the PWM controller and associated wire harnesses I found more than 8 inches of wire inside the unit — plenty of opportunity to couple noise to the harness.

The input bundle consisted of two power input leads, two control leads, and one chassis ground. I twisted the relevant pairs together and then twisted the ground lead around both pairs. I added two ferrite beads inside the PWM controller for good measure, one each on the power input and output pairs (see Figure 2).

Success! Twisting wire pairs reduced the noise to S-0. I can just hear it in there at the noise level on 20 meters. I chose to leave the external ferrite beads on the cable for good measure (see Figure 3).

Solutions in Curaçao

My newfound knowledge helped me tackle a similar problem at PJ2T, Signal Point on Curaçao. The noise there was a constant 10 dB above S-9 across 20 meters. I traced the noise to a wall-mounted air conditioner unit. Noise was present any time the compressor motor was running.

This is a high-efficiency unit that uses an inverter to drive the compressor. The output cables that drive the compressor and fan were accessible, but the input cabling was not. A significant amount of work would have been required to get to the input bundle, given where the unit was mounted.

I twisted each wire bundle as tightly as I could (see Figure 4). I also clipped on ferrite beads as close to the inverter as possible. I then fired up the air conditioner and went inside to listen on 20 meters, but I couldn't hear any noise. Success!

Summary

My experience showed that twisting wire pairs together has a significant effect on reducing radiated emissions and is likely the single most important thing you can do to reduce radiation or minimize susceptibility. Adding clip-on ferrites provides an incremental benefit.

Many thanks to Ken Cechura, KC9UMR, for his valuable help in sorting out a solution.

Bob Lee, W0GXA, was first licensed in 1976 at age 16. He is a graduate of the University of Iowa with a BS in Electrical Engineering ('82) and an MBA ('92). His technical experience focused on analog and digital circuit design, and later on systems engineering. He worked for the US Navy and a banking equipment firm. Over the past 27 years, he worked at Rockwell Collins in avionics systems for business and air transport aircraft. He is currently Director of Commercial Systems Strategy. Bob is a CW operator who enjoys contesting and experimenting with antennas. He is a member of the Eastern Iowa DX Association and Society of Midwest Contesters. You can reach Bob at 2266 Prairie School Rd, Ely, IA 52227 and **rclee2266@gmail.com**.

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