**The following article was published in The Canadian Amateur magazine, May/June 2018, pages 16 – 18.**
**It is reproduced here with the permission of TCA.**

**June 2018, Pickering Ontario**

# "An Unexpected Source of QRM on 220 MHz..."

# “An Unexpected Source of QRM on 220 MHz…”

**Don Dorward, VA3DDN**

## THE PROBLEM

For more than a year I have been plagued by unknown interference or QRM that comes in on one specific 1.25 metre repeater frequency at my home QTH. The frequency is 224.860 MHz, which happens to be the home of VE3BEG – the Toronto FM Communications Society.

The interfering signal is so strong, annoying and persistent that I can no longer tolerate monitoring this frequency for any period of time. Just turn up the squelch, you say? Well, squelch control at max sometimes has no effect!

I have a Jetstream JT220m transceiver in my shack using a Comet CX-333 antenna at 35 feet in the backyard, as well as an ADI AR-247 in another part of the house using a separate 220 J-Pole antenna outside. For mobile operation, I have the Alinco DR-235 in my car, and for portable the Kenwood TH-F6A handheld (HT). Note that all four of these radios pick up the same signal.

Of course for the two fixed location house radios, the interference was there 24/7, sometimes stronger or weaker, and oddly, sometimes peaking 5 kHz lower/higher.

I noticed on the mobile in my car that as soon as I moved 15 feet down my driveway away from the house, the noise stops. On the HT, the noise signal was strongest in my kitchen and basement on the east side of my house, as well as outside between my house and my neighbour’s house. In fact, this led me to “carefully” ask my neighbour if they had recently installed any RF devices such as security alarms or having some other form of rogue transmitter that could be the culprit.

### What I didn’t do soon enough!

The first thing to determine in locating the source is to find out if the interference is originating from within one’s own house or from somewhere outside.

Looking back, I see this basic advice is mentioned in a number of publications by the American Radio Relay League. The caveat is:

*“Do not assume that the interference is not coming from your own house!”*

Eventually, I came to this realization myself and flipped off the main breaker to my electrical panel. To my amazement, the interference was gone! Next, with main breaker back on, I unscrewed one-by-one, each of the 28 fuses in my electrical panel. And there it was, the noxious signal was coming from my own house – and from my 2015 Sears Kenmore dishwasher!

This was indeed a learning experience for me, as I hope it will be for others.

## MEASUREMENTS

At first, I used only my Kenwood THF-6A HT with a six-inch stub “sniffer” antenna to track down the 224.860 signal. At that time I had not even thought of harmonics from a lower frequency source. The first confirmation of the presence of the microprocessor clock harmonics was made with my friend Ken Grant, VE3FIT, who kindly brought his Rigol DSA815 spectrum analyzer over.

The originating 8 MHz was difficult to pick out of the high noise floor, however we easily saw the 7th, 8th and 9th harmonics at 56.2, 64.2 and 72.3 MHz. Looking at a Table of the 8.03 harmonics shows that other radio bands may also be affected such as the aircraft band, the 2m Amateur band and so on.

Subsequently, I used my SDRplay RSP1 receiver with a short pick-up antenna placed close to the dishwasher control panel. The 224.855 MHz signal is shown in Figure 1 below and the 8.03 MHz clock is shown in Figure 2 on the next page. Verification was easy just by removing the fuse at my electrical panel and watching the noise signal disappear.

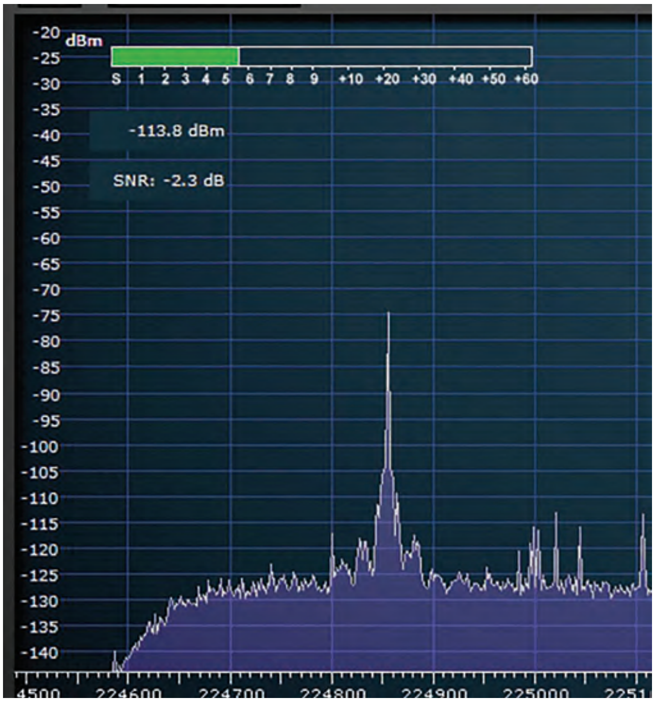



**Figure 1: The 224.855 MHz signal.**

### Authors’ Comments and Cautions

Readers are reminded that the experiments documented in this article are just that – experiments – and were done for informational purposes.

I am not recommending that any of them be carried out, especially noting that neither offered improvement.

The “fallback” solution using the remote operation AC line switch, still involves the routing and handling of 120 vac wiring and should only be carried out by licensed electricians or technically qualified individuals.

#### Electromagnetic Interference (EMI) or Radio Frequency Interference (RFI)?

EMI is actually any frequency of electrical noise, whereas RFI is a specific subset of electrical noise on the EMI spectrum. There are two types of EMI. Conducted EMI is unwanted high frequencies that ride on the power-line AC wave form. Radiated EMI is similar to an unwanted radio broadcast being emitted from the power lines.

#### No Easy Fix for EMI

At the time of writing this piece, the relevant standards for unintentional radiators producing conducted and radiated emissions are US CFR Title 47, part 15, and the Canadian ICES-003. Both of these standards have listed dishwashers as being **exempt** from these requirements.

My own dishwasher attests to the reasons for the exemptions.

I decided to write about this experience for two reasons: first to illustrate how many users of the radio spectrum can be affected by EMI/RFI; and second, perhaps it’s time for our regulatory bodies to take a second look at removing these exemptions.

## Analysis

This model dishwasher has an electronic control assembly (ECA), part #807024501 that is mounted in the dishwasher door inside a moisture-proof cover. It uses a 40-pin microprocessor marked SF2112-K4501 with an 8 MHz clock, provided by a ceramic resonator (see Figure 3).

The resonator (shown in blue in the inset at the top right of Figure 3) is labelled X1 and sits just above the microprocessor in the photo.The harmonics of this clock signal are extremely robust and extend all the way up to 220 MHz (28th harmonic). It is important to note that any frequency drift at the 8 MHz fundamental of the resonator will be multiplied by the harmonic number at higher frequencies. I don't know the characteristics of this particular resonator, but in general most drift higher in frequency with increasing temperature. I have heard 10 ppm per degree Celsius is typical.

The environment inside the dishwasher door likely gets quite warm, approaching the hot water temperature which could typically be 130 degrees Fahrenheit or approximately 55 degrees Celsius – a change of 20 degrees Celsius from ambient temperature. This helps to explain why on some days I found the RFI noise peaking as low as 224.820 where it was not an issue for me and on others at 224.860 which made the repeater unusable. (**Note:** an 800 Hz change at 8 MHz becomes 22 kHz at 224.8!)

What makes the situation even worse is that the machine is always connected to the AC line in order keep the on-off pushbuttons on the control panel alive. In other words, the machine is never fully "off", even though you may think it is. No matter if it is on or off, running or stopped, there was little difference to the interfering signal.

The ECA #807024501 is a popular one for replacement as Google returns a number of hits on it. In addition to Kenmore, the same ECA is also used on some Electrolux and Frigidaire models, possibly with different features provided by the many unpopulated parts, shown as outlines on the ECA PC board.

With no schematic available, it is not possible to evaluate the circuit, beyond saying there appears to have been little concern taken for the prevention of RF interference, either conducted or radiated, both of which seem to be present. There is no copper ground plane on the ECA PC board, no ground connections to the dishwasher frame from it and little evidence of decoupling capacitors.

The board is fastened to a plastic panel inside the front door of the dishwasher, with a molded plastic cover squeezed against a flat sealing gasket. A 15-conductor flat ribbon cable exits the sealed area by simple compression between the plastic cover and the gasket. This ribbon cable reaches up to the front panel pushbuttons and LEDs (see Figure 4 below) which, with no apparent RF decoupling, provides a great exit path for radiated RFI. This is easily confirmed by moving the THF-6A HT with a six-inch stub "sniffer" antenna close to this area.

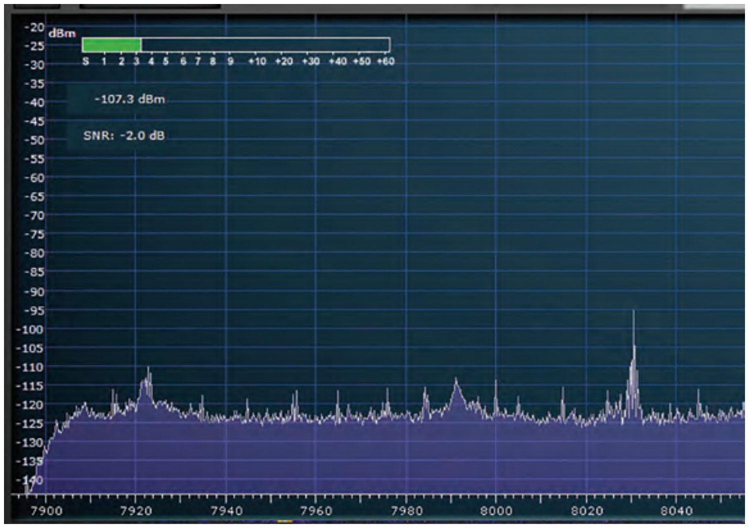



Figure 2: The 8.03 MHz clock.

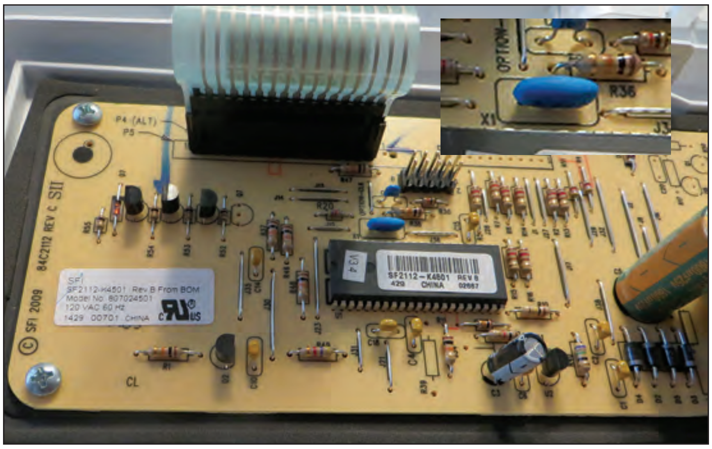


Figure 3: The Kenmore dishwasher's electronic control assembly.

Although the machine has a white-painted steel front panel, it has proven ineffective for RFI shielding. The panel ends just below the pushbutton area and, in any case, is ineffectively grounded to the dishwasher frame via only two of the four screws which fasten it. I noted too, that the heads of these screws sit on the paint!

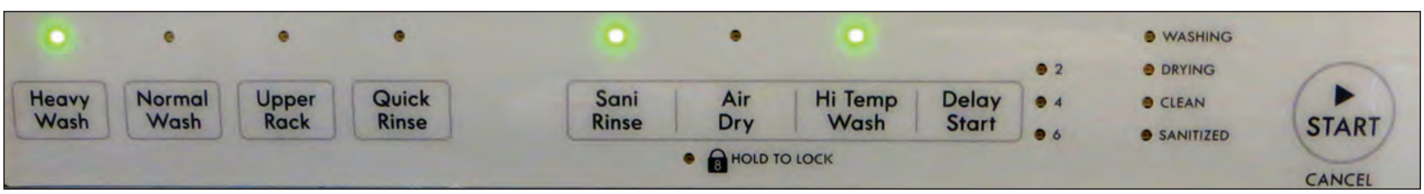
## Attempted Fixes / Improvements

I realized that a truly effective fix would involve a combination of major ECA revision, as well as grounding and harness changes, which was clearly much too difficult and impractical to carry out. Therefore I decided to try some basic, simple improvements to see if the problem could be mitigated at all.

1) The first "improvement" I tried was to add a ceramic bypass capacitor of 0.0056 UFd, soldered across the AC input to the ECA pc board (see Figure 5 on the next page). I also tried to improve the ground connection of the steel front panel by sanding off the paint under the mounting screw heads.

**Result:** There was no noticeable improvement or change to the noise signal.

Figure 4: The front panel pushbuttons and LEDs.



2) The second "improvement" was to add a two-stage commercial AC line filter in series with the AC line to the dishwasher. Ideally, the filter would be mounted to the dishwasher frame, close to the ECA assembly. This was physically too difficult for an old guy like me to do, so I compromised by locating the filter beneath the dishwasher where the AC wiring came through the kitchen floor. This would leave about three feet of AC wiring between the dishwasher and the AC line filter.

Not an ideal installation, being a bit too far from the RFI source, but I hoped to reduce the conducted EMI from getting into the electrical panel and from there to other parts of the house. I used an over-sized standard square AC outlet box to mount the line filter in (see Figure 6).

**Result:** At first, this appeared to substantially reduce the dishwasher RFI introduced into the AC wiring of the house. However, I was fooled by the instability of the noise signal as mentioned earlier. Alas, the RFI was still there, just at possibly a slightly lower level.

At this point I concluded that there was to be no easy high-tech fix. The simplest way of removing the RFI interfering with my Amateur Radio activities was to add a real on-off (SPST) switch to the dishwasher. This way, I could disconnect the AC power circuit when I was not using the machine.

I also decided not to drill a hole into the front of the dishwasher and instead to use an AC wireless remote switch. Such wireless switches are often used outdoors to control landscape lighting, pond pumps and so on. The model I purchased was rated at 15 amps and claimed a remote control range of up to 100 feet. Figure 7 shows the switch body and the remote on-off controller.

Such wireless switches are readily available from Home Depot, Lowes, Canadian Tire, etc.

**References:** Hunting Down RF Noises, Michael Foerster, W0IH, *QST* February 2015.

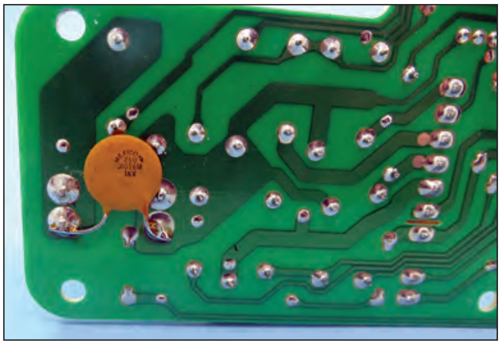


Figure 5: Ceramic bypass capacitor on the ECA solder side.


Figure 6: AC Line Filter mounted in an AC outlet box.


Figure 7: AC wireless switch with the remote on-off controller.

*Don Dorward, VA3DDN, has had 43+ years in the electronics industry including vacuum tube manufacturing, semiconductor and component testing, R&D, ISO Quality Systems, Regulatory Affairs, UL/CSA/EU/CE/EMC compliance, Environmental testing, Standards and Calibration. He is a Life Member of the Institute of Electrical and Electronics Engineers (IEEE). He has been an Amateur Radio operator (VA3DDN) since 2002 and is a member of the American Radio Relay League (ARRL), Radio Amateurs of Canada (RAC) and the Radio Society of Great Britain (RSGB).*

TCA

## Revised Canadian Table of Frequency Allocations

**Now includes additional 15 kHz for 60 Metre Band with the same power limits as earlier allocated spot frequencies.**

In August 2017, the Department of Innovation, Science and Economic Development Canada (ISED) issued "Proposed Revisions to the Canadian Table of Frequency Allocations". These proposed changes followed decisions made at the World Radiocommunications Conference in 2015 (WRC-15) that included a 15 kHz-wide allocation for the Amateur Service in the 60 metre band. The proposed revisions to the Table would retain the original five 5 MHz spot frequencies with 100 watts of effective radiated power, but restrict the new 15 kHz allocation to only 15 watts (eirp), the agreement at WRC-15 that accommodated concerns of a few countries over possible interference to their domestic communications. Decisions these days at World Radio Conferences require unanimous consent of all member nations.

Radio Amateurs of Canada noted in its response to the proposed changes that there had been no reports of interference from Amateur Radio operations on the existing five 60m spot frequencies following their use in Canada since 2014 and in the USA for even longer. Further, the rationale for allocating the spot frequencies had been based on the value of 60m for emergency communications and the low power limit adopted at the WRC would seriously limit this use. Other responses from the Radio Advisory Board of Canada (of which RAC is a member organization), the Ottawa Valley Mobile Radio Club, the Marconi Radio Club of Newfoundland and several individual Radio Amateurs also recommended 100 watts. The new allocation will be more effective and manageable for domestic SSB communications and consistent with the existing use of the band on the five spot frequencies now enjoyed by Canadian Amateurs. The responses can be read at: https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11346.html

We are happy to report that in their release of the Revised Table of Frequency Allocations (http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10759.html) issued on April 13, 2018, ISED has addressed the concerns of the Canadian Amateur Radio community. The Revised Table now allocates the band 5351.5 kHz - 5366.5 kHz (which overlaps one of the previous 60m spot frequencies) and the four previously allocated spot frequencies (5332, 5348, 5373 and 5405 kHz). The conditions for the use of the band and spot frequencies remain the same as those governing the spot frequencies previously: maximum effective radiated power of 100 watts PEP, 2.8 kHz emission bandwidth and permitted

– continued on page 27