The Great RFI Hunt

Diligent analysis — including unplugging everything in the house — reveals the culprit.

Robert Wilson, NTØA

My return to ham radio after a 10 year break has been one head scratching exercise after another. The most frustrating has been the one that most hams face at one time or another — electromagnetic interference (EMI) or radio frequency interference (RFI) from unknown sources. I upgraded an old computer to use for logging and other ham shack activities. When I moved it out to the ham shack and turned it on, my education began.

Signals Can be Good News or Bad

The computer worked flawlessly, but put a solid S-5 signal on all the HF bands. Sometimes it was uniform across a band, and sometimes it was spotty or uneven. At times it was 10 to 20 dB over S-9. The RFI from the computer covered all but the loudest signals on each band. I didn't expect that since I had had my laptop out there earlier and it did not cause any problem.

Making Sense of the Signals

I Googled *ham radio computer generated RFI* and bookmarked the best sites. I read them all and then started the troubleshooting procedure. With the coax removed from the radio, I started out by slowly tuning through all of the bands. Whenever I heard a birdie, hiss, hash or growl, I shut the computer and monitor down to see if they were causing the problem.

On 80 meters the computer was not heard at all. On 40 meters the computer could be faintly heard around 7.214 MHz, but without any movement of the S meter. On 30 meters the computer could be heard slightly but it was not enough to cover any real signal on the band. The 20 and 15 meter bands were an entirely different story. I could hear RFI as described in Table 1.

Table 1
RFI Received Without Antenna Connected

Frequency Range (MHz)	Received Indication
14.010-14.015	soft hash, no S meter movement
14.055-14.061	soft hash, no S meter movement
14.065-14.070	soft hash, no S meter movement
14.107-14.117	loud hash, S-3+
14.155-14.160	soft hash, no S meter movement
14.185-14.189	soft hash, no S meter movement
14.208-14.215	loud hash, S-3+
21.067-21.072	soft hash

Then I connected coax to the radio and spot checked the frequencies in Table 1. As one would expect, the RFI was stronger and more pronounced with the coax connected to the radio and stronger when connected to the antenna than to the dummy load, although it could still be heard in the dummy load position.

Next I checked the effect of removing the keyboard and/or the mouse. The S meter reading dropped 60 to 70% if the keyboard was removed and dropped the rest of the way when the mouse was disconnected. This was an artificial *eureka!* moment. I then tried different keyboards and mice. Some were better than others but the original combination was the best.

I tuned the rig to 14.112 MHz and disconnected the mouse and keyboard. The noise level dropped dramatically. I then turned on my external keyer and the rig became almost silent and I was unable to explain why.[1] I noted the same effect on white noise when the rig was connected to an antenna with the computer off and the mouse and keyboard disconnected.

Time to Experiment

I turned off the computer, turned off the keyer and disconnected the mouse and keyboard. I tuned the radio to 14.112 MHz and connected the mouse with no noticeable effect. I disconnected the mouse and connected the keyboard with the computer and monitor still off and as with the keyboard PS-2 plug between 1/32 to 1/16 inch from the computer PS-2 socket, the

[1]J.Garrett, WB4VVF, and D. Contini, W4YUU, "The Accu-Memory," *QST*, Aug 1975, pp 11-20.

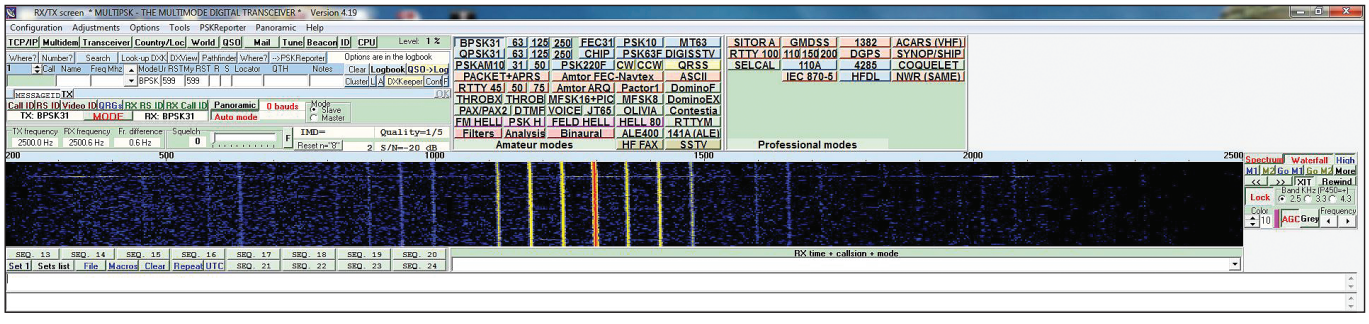

Figure 1 — MultiPSK waterfall display screen shot (with the lower half of the screen cut off) showing the interference that came from my hot tub on the other side of the wall of my ham shack. A change of ham shack location as well as new Times Microwave LMR400 coax significantly reduced that interference.

interference returned at the original S3 level. What is going on? I tried other keyboards and they all had similar, but less pronounced, effects. When I reached up and touched the top of my keyer (still turned off) the RFI went away. I began to suspect I was a victim of *Candid Camera* or *America's Funniest Home Videos*.

I thought about the problem and decided that the computer keyboard line must be acting as either an RFI connection device or as a rectifying antenna for RF energy in the area. The sensible solution seemed to be to put ferrite beads around all the cables in and out of computer. After a fast trip to the local Radio Shack, I installed ferrite beads on each end of each cable into or out of the computer as well as on the radio power cord near the radio. I powered up the computer and concluded that $25 worth of ferrite beads didn't do a thing, except increase the attenuation effect when the keyer was touched. What in the world was going on?

One of the common RFI cures is to ground all of the chassis to the same ground, so I built two new ground cables (the radio and external VFO were already grounded to each other) and daisy chained everything together so that the chassis of each was at the same RF potential. I repeated some tests. The common ground had absolutely no impact. The noise level was exactly the same as before.

I then turned on the keyer, and the computer RFI disappeared completely, except for the hash around 14.112 MHz, which never went away.

Starting to Get Frustrated!

It appeared that while my earlier touching of the keyer silenced the RFI, I may have been adding some unknown capacitance to the RFI network, and that capacitance trapped the RFI in some way. In a similar fashion the keyer was acting as a choke to cut out the RFI. If I knew what that capacitance was and where in the circuit it was, perhaps I could solder in a permanent fix. I concluded that RFI must be feminine and capacitance must be masculine because I understood capacitance, but I could not solve the RFI unhappiness except by accident.

I continued troubleshooting by removing power from everything in the house with the exception of the ham shack by turning off every circuit breaker except the one supplying the ham shack. The result was zero impact on the level of the interference. I was beginning to suspect that the problem lay in the power lines and transformers. It was also possible that the source lay with some equipment in the local industrial park, but because the interference did not vary with the time of the day, I doubted that the problem lay there. In any case, I desperately needed help of someone because I had neither the equipment capable of pinpointing the source nor the experience necessary to successfully hunt down the source or sources.

Help Arrives

Jerome Chamberlin, WAØJRJ, came to the rescue and helped me find out that the source of the RFI. It was literally in my ham shack!

We spent most of one morning trying to track down the source of the noise by using both a mobile HF rig in his car and a scanner with a hand held beam antenna. We found a dozen potential sources within ½ mile of my house, but nothing clearly identifiable as an offending point source. At the end of the third trip around the neighborhood with the mobile rig tuned to one of the offending frequencies, the interference became louder and louder the closer we came to my garage.

It was then that we had Eureka moment #2 — we realized that the problem was in the house.

We made a trip around both the exterior and interior of the house with the following results:

- The 80 meter dipole and open feed line pick up the signal.
- My metal gutters pick up the signal more than the dipole and feed line.
- Nothing was identifiable as a point source.

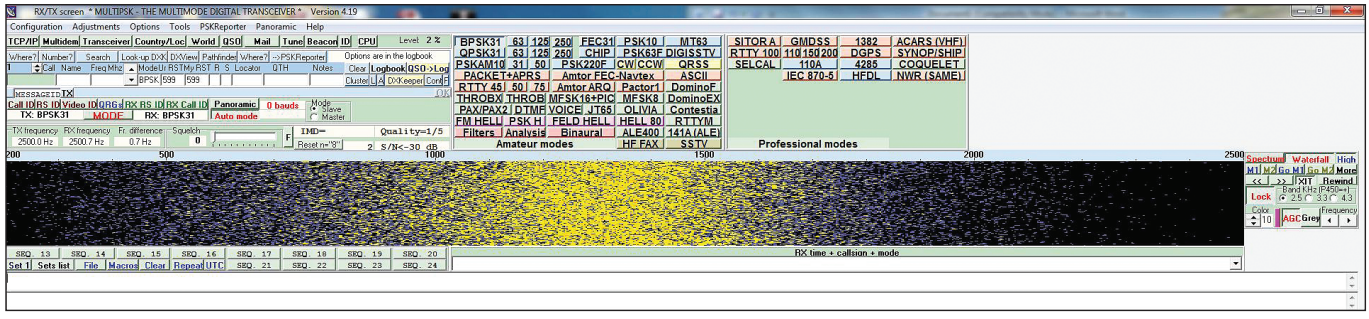

Figure 2 — This interference was seen on 14,005.6, 14,104.9, 14,203.9, 14,303.3, 18,077.4, 21,057.6, 21,156.9, 21,256.0 and 24,931.2 kHz. It decreased in strength as the frequency increased. The fact that the signal repeated roughly every 100 kHz effectively rendered those bands unusable. This was traced to my computer power supply.

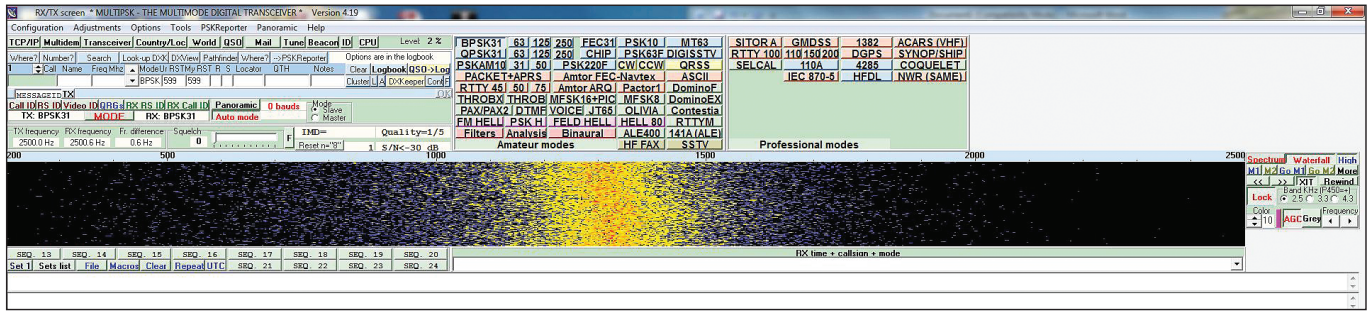

Figure 3 — This interference was seen on 6952.3, 7051.0, 7151.07 and 7250.1 kHz. The fact that the signal repeated roughly every 100 kHz effectively rendered 40 meters unusable.

We went back to ground zero by electrically shutting the house down completely. The interference received on the battery powered mobile HF went away. Finally some progress.

We turned circuit breakers back on one at a time, and when I closed the circuit breaker for the ham shack, the RFI came back. Turn that breaker off and the noise was gone. That would explain why the noise still existed when everything but the shack was shut down, but what could be producing the noise. Nothing was turned on in the shack. The computer was off, the monitor was off, the oscilloscope was off and all of the radio gear was off. Even the lights were off.

By physically unplugging every electrical cord in the shack and plugging them back in one at a time the culprit was revealed to be the computer power supply. Even though the computer was not powered on, the power supply was radiating just like an old spark gap transmitter. With the computer unplugged, some RFI that was previously hidden by the power supply noise revealed itself. All of the newly discovered RFI consisted of discrete signals that I thought I could live with if I were not able to track them down. As Paul Harvey would say, "And now you know the rest of the story."

When I posted my pleas for help, I knew that I had a number of different kinds of RFI:

- Broadband noise across every band.
- Discrete noise spikes or "strobes" across every band.
- Occasional strong signals with equally spaced, decreasing strength "echoes" above and below the main signal.
- Occasional "two-tone" RFI (see Figure 1).

The two-tone RFI was quickly traced to the hot tub that sits on our patio 3 feet from the back wall of my ham shack. I contacted the spa manufacturer and they suggested the problem was the heater. They have not yet responded to my suggestion that the source is the power supply for the circuit board that controls the spa. I can work around that problem by simply powering down the spa when I am on the air. I'll see if some strategically placed ferrite beads help. I could have worked around that problem by simply powering down the spa when I was on the air, but this bit of RFI was eliminated when I moved my ham shack from the garage to the basement, more proof that gaining distance from something bad is a good thing.

The broadband RFI (Figures 2, 3 and 4) was traced to the power supply in the computer in the ham shack. Based on report of other hams on the Internet I ordered a PC Power (**www.pcpower.com**) model Silencer 760W from **Amazon.com**. It is a large, heavy power supply for an ATX motherboard. After I installed it, all of the broadband noise was gone. I highly recommend the PC Power products as a solution to solve an RFI problem generated by a computer power supply.

Discrete Noise Spikes

The remaining RFI that permeated every HF band (Figure 5) was tracked down to my Linksys WRT54GS wireless router. From the many discussions on the Internet it appeared that this was a common problem with this (discontinued) model router, and that a Netgear product offered the best hope for a solution. Netgear systems engineers advised that the best choice for an HF sensitive environment is the WNDR4000(N750). Reluctantly I bought one in the hope that it would solve the problem.

As part of the replacement process I setup the new Netgear N750 and my old Linksys WRT54GS router, tuned my HF rig to a frequency that previous tests had revealed was unusable because of interference from the Linksys router, and then switched between the Linksys and the Netgear routers while checking the HF rig for the level of interference. The Linksys router produced RFI and the Netgear router did not.

I was sure I had found and corrected the problem, but several responders to my request for information about the Netgear router said to make sure that the wall wart was not the culprit. To eliminate that possibility, I depowered the Linksys wall wart and powered up the Netgear router with the Netgear wall

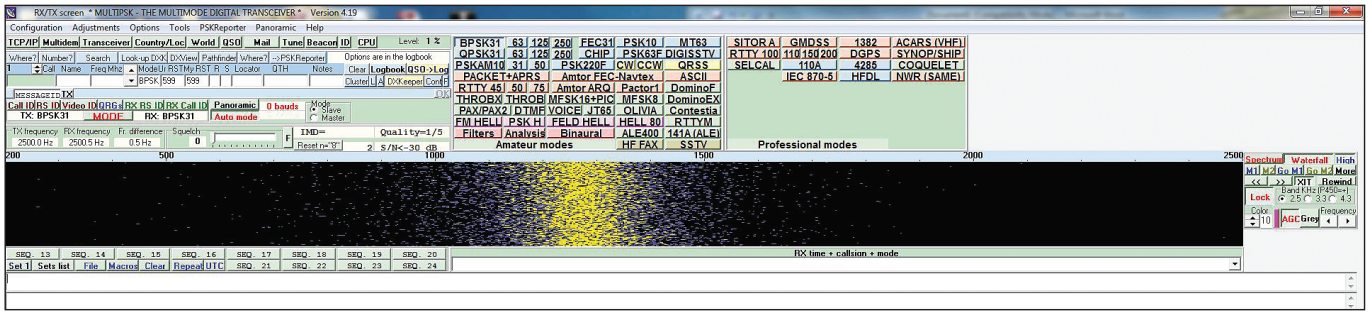

Figure 4 — This single frequency interference appeared on 7349.8 kHz.

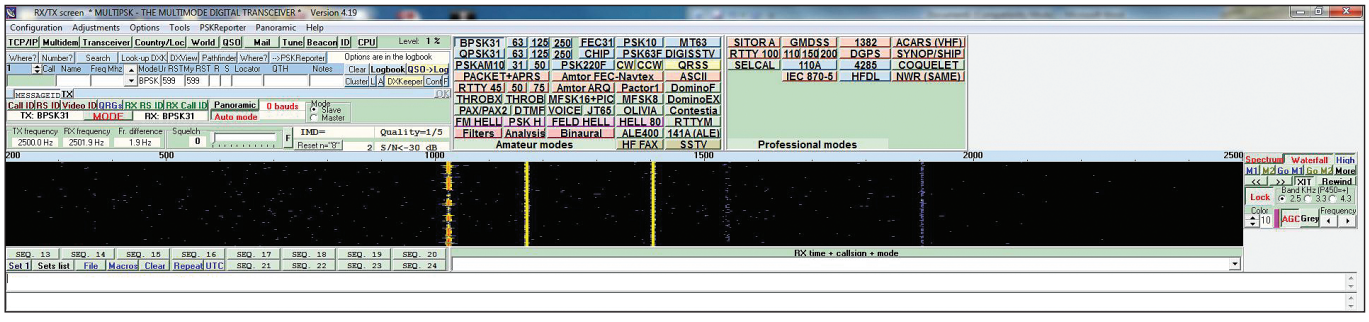

Figure 5 — This interference was seen on 14,150.3, 14,211.4, 14,272.4, 21.050.4, 21,211.5 and 21,172.5 kHz. I don't believe I ever found the source of this signal.

wart. All RFI disappeared from the HF bands. Then I depowered the Netgear router and used the Netgear wall wart to power the Linksys router. This led to Eureka moment #3 because the band crushing RFI was back with a vengeance. I was sure that I had proved that the problem was the Linksys router and not the wall wart, but to be sure, I depowered the Linksys and used the Linksys wall wart to power up the Netgear router, and the RFI did not return. The Eureka moment was validated. There was no doubt that the source of that RFI was the Linksys router.

I set up the Netgear router with its own wall wart, connected a computer to the router with a CAT5 cable, installed the software, and set up the router. Next I brought all of the wireless computers on line and made sure they had network and Internet access. Once all of the wireless connections were made, I checked the rig again. The RFI associated with the Linksys computer was still gone. I hooked up the other two remaining CAT5 connections (one computer and one printer) and went in to watch the news. After the news I went out to the shack and turned on the rig. The signal hiding RFI was back as strong as ever which led to Eureka moment #4. Obviously I had left the Linksys router powered up. Back to computer central only to discover that the Linksys router and wall wart were sitting in a box. Something else was causing the RFI, but what?

I unplugged all three CAT5 cables and the RFI disappeared. Plugging the CAT5 cables in one at a time led to Eureka moment #5 and the final solution. Two of the three CAT5 cables were bad in that they were acting as transmitting antennas. When the cables were replaced, the RFI either disappeared or was so attenuated so much that it was not a factor. Finally success. I thought that I had conquered the RFI demon.

Well, almost — some pesky S-7 birdies still remained, and the plasma HDTV was producing RFI that was worse than anything experienced to date. To this point, the most frustrating thing I had learned was that eliminating RFI is like peeling an onion. You peel off one layer only to discover that there is yet another stinky, tear producing layer below it.

Bird Hunting with Toroids

The remaining S-7 and weaker birdies were tracked to the CAT5 UTP (unshielded twisted pair) cables hooked to the Linksys router.

I put at least one type 31 toroid with 12 to 14 turns on the end of each cable. The impact was minimal. Additional troubleshooting revealed that the culprit was the Time Warner Cable supplied Cisco cable modem and the primary radiator was the CAT5 cable between the modem and the router. Since the impedance of multiple toroidal chokes in series is additive, I put seven toroids on the modem to router CAT5 cable.

The router/modem RFI on 80 and 40 meters was greatly reduced, but on 20 meters and above the reduction was only 6 dB. That left discrete S-5 noise spikes across the upper HF bands. Still looking for an inexpensive solution I researched shielded cables. CAT9 STP (shielded twisted pair) would have provided the greatest attenuation, but I could not find any ready-made CAT9 cables, and the smallest length of CAT9 cable I could find was a 1000 foot spool. The specs on CAT6 STP looked very good and I found some 5 meter CAT6 STP cables with shielded RJ-45 connectors on **Amazon.com** for about $3 each.

Two days later I plugged in a raw cable and ran a test. The result was slightly less attenuation than the CAT5 UTP cable with seven 12 to 14 turn toroids. A type 31 toroid with 12 turns at each end of the CAT6 cable provided minimal additional attenuation.

Perhaps toroids of a different material would do the trick. When they arrived, I added a type 61 toroid to the end of the CAT6 STP cable that already had a type 31 toroid at each end. *Voilà!* The modem/router-generated RFI on 15 and 20 meters dropped to S-0. It's still there, but it doesn't hide weak signals unless they are on the exact same frequency.

Lessons Learned to Minimize Computer Generated RFI

- Apparently there is no consumer grade Wi-Fi router that is free of RFI.
- Never use unshielded cable in your home network.
- At a minimum, put one Fair-Rite type 31 and one Fair-Rite type 61 toroid at each end of each of your cables.
- Never use an unfiltered power supply in your computer.
- I have found that I can rely on power supplies manufactured by PC Power. They cost considerably more, but they eliminate power supply RFI.

I should also note that the type 31 toroids alone cut out the router RFI on 160 meters through 40 meters and the Type 61 toroids took care of 30 through 17 meters. The noise on 15 meters was greatly reduced, but there is still a significant noise on 12 and 10 meters. I suspect that either a type 43 or type 73 toroid to each end of the modem-router cable would knock out the RFI on 15 through 10 meters, but I have not taken the time to double check.

I have not completely conquered the RFI demon, but I've bloodied his lip and he's gasping for breath!

ARRL Life Member and Amateur Extra class licensee Bob Wilson, NT0A, was trained as a photojournalist at the University of Missouri. He, however, spent most of his working life in one aircraft cockpit or another. Immediately after graduation, Bob entered flight training with the US Navy and earned his wings in the fall of 1964. His first two cruises in 1965 and 1966 were spent flying the Douglas A-4E single seat attack aircraft in daily strike sorties. Bob was awarded the Distinguished Flying Cross, 13 Air Medals, and three Navy Commendation medals with combat V. Following a short stint with Continental Airlines, he returned to the Navy for an additional seven years. He then returned to Continental, retiring in 2002 as a captain of a DC-10 aircraft.

Bob was first licensed as WA6MIE in 1977. He upgraded to Extra Class in the 1980s. His favorite operating mode is CW and his favorite events are ARRL Field Day and Straight Key Night. Bob is also active in the Navy/Marine Corps MARS program. You can reach Bob at 5548 NW Platte Dr, Riverside, MO, 64150-1415 or at **nt0a@kc.rr.com**.

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Strays

QST Congratulates...

William A. Davis, W9KIC, an ARRL Life Member and professor of electrical and computer engineering in the College of Engineering at Virginia Tech, for having the title of "professor emeritus" conferred upon him by the Virginia Tech Board of Visitors.

A member of the Virginia Tech community since 1978, Davis has made significant contributions to research in the areas of antennas, electromagnetic fields, microwave and nonlinear measurements, communications circuits, radio engineering and wireless applications. He has received more than $3 million in external research funding and has been awarded two US patents.

Davis is a senior member of the Institute of Electronics and Electrical Engineers (IEEE) and is the current chair of Commission A (Metrology) of the International Union of Radio Science (URSI).