Building An Ultrasonic System to Pinpoint Arcing RFI Sources

Project and Article by KK4ICE - Dan Gunter
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Having been plagued for over a year with Radio Frequency Interference (RFI) which often exceeded S9 on the HF bands, I decided it was time to take some action. Not only did I need to identify what *type* of RFI it was, but I needed to find the exact source so that I could either fix it or get in touch with someone who could. Thus began my journey into using various tools -- including ultrasonic detection -- in RFI investigation and remediation

I began by checking for RFI sources within my QTH. Shutting off all the breakers in my home and operating my HF station via battery power did not remedy the problem. Disconnecting the outdoor antennas did make the noise go away. These two initial steps verified that it was a source external to my home and that it was being picked up by the antennas. That still left countless possibilities as potential sources for my RFI troubles. The next step was to try to narrow down the geographic location of the source as closely as possible.

The noise was always present; however, it seemed to peak on warm, dry days -- a clue. So, on a day when it was hitting 10 on the S-meter of my rig, I began my search. Tuning an AM car radio off-station, I could hear the noise everywhere within about a half mile radius of my QTH. Not a lot of help. So I used a handie-talkie tuned to 130 MHz in AM mode. The noise was there, sounding just like it did coming into my HF base rig on 160 Meters through 6 Meters. But now I was able to do a little riding around the neighborhood and pinpoint the area of the loudest noise to within two or three adjacent utility poles. The nearest of these poles was the third one from my house. It was not surprising that the noise dropped somewhat at my house on 130 MHz. In cases of RFI, the lower the frequency it is propagating on, the farther away it can be heard.

Back at the shack I used my HF base rig and an oscilloscope to take a look at noise (no pun intended.) By tuning to a frequency with no QSO in progress and no signals of any other type, I fed the demodulated audio to my digitizing oscilloscope. What I saw were noise bursts at 120 Hz intervals (see Fig. 1.) This was revealing in itself, although at first it might sound confusing, as most people think about “60 cycle hum” and thus would expect to see something happening at 60 Hz. With arcing on power line-related equipment, however, we

Fig. 1: Adjusting the delta time markers to the beginning of adjacent RFI noise bursts in the demodulated AM audio showed them to be occurring at 120 Hz intervals, indicative of possible high voltage arcing.

need to consider what actually occurs. The arcing takes place when there is sufficient voltage potential to overcome the resistance of air or some other medium and “jump” between connectors, conductors, devices, hardware, etc. The voltage actually peaks twice per A.C. cycle -- a positive peak on the first half of the cycle, then an equal but negative peak on the second half. This creates two arcing events during each cycle. 60 Hz x 2 = 120 Hz. Seeing these bursts of noise on the scope at 120 Hz intervals pointed strongly to the likelihood of a problem with arcing on one of the suspect poles.

Now that the source had been potentially narrowed down to electrical arcing on one of three utility poles, the next problem was to identify the exact pole it was coming from -- and hopefully what area of that pole it was coming from. In fact, I wanted to be able to pinpoint the source as finitely as possible. It was obvious that I would have to call the local power company to address the problem. My hunch was that the closer I could direct them to the specific source, the less time and manpower (i.e., dollars) would have to be invested on their part in fixing the problem. The question was how to accomplish this.

It is sometimes possible to narrow the source down to a particular pole using highly directional antennas such as yagis along with VHF and UHF receivers. If the RFI is detectable on UHF (in this case it was at 440 MHz using a non-directional factory H/T antenna) you’re usually very close to the source. It seemed to be strongest at one particular pole, but could be faintly heard at the two others. Being unable to say with absolute certainty that the suspect pole was home to the offending RFI source, I resumed my research into RFI characteristics and troubleshooting.

When electrical arcing occurs, it produces several things. There is RFI energy, which was the crux of this whole matter to begin with. There is sometimes visible light. There is also some heat generated. Thermal imaging cameras occasionally (but not always) detect arcing on power distribution systems by displaying the temperature differential. Given that these typically cost more than any vehicle I have ever owned, obtaining an infrared/thermal imaging camera was not feasible. So, what else does eletrical arcing produce that might be pinpointed with the proper equipment (i.e., “affordable for a ham who didn’t just hit the Powerball lottery”?) Ultrasonic energy, for one thing -- sounds above the range of human hearing. I then began researching ultrasonic equipment and its capabilities. I discovered that with the use of ultrasonic transducers and a device amplify the ultrasonic sound and convert it by shifting it to within the frequency range of human hearing, it is possible to actually “hear” the arcing as it occurs. Since there is not a lot of ultrasonic sound being produced in nature (at least not as compared to “audible” sound) there is an inherent advantage to ultrasonic detection: it can be pretty easily detected without having to try to sort it out from any competing noise. This looked to be the likely solution. I just needed to put together the right equipment.

Fig. 2: The ultrasonic detection kit which was purchased as the foundation of my arcing RFI location system.

I purchased a used ultrasonic detection kit (Fig. 2.) The kit contained an ultrasonic amplifier/detector with a meter and speaker, a set of noise canceling headphones, a contact probe, and a sound concentrator. The original hand-held probe -- which did not require direct physical contact) was missing from the kit. That was not a problem, as I already knew I would be ordering some additional transducers to build a few additional sensors, one of which would be highly directional if all went as planned.

After procuring a pair of additional transducers, I built a hand-held probe with one of them by installing it in a hold drilled in a PVC end cap and placing it one a short section of PVC pipe. I drilled a hold in the center

Fig. 3: Homemade ultrasonic hand probe.

of a larger end cap and ground out the inside of it with a grinding tool. Then I ground down the outside of the end cap with the transducer installed in it. Feeding the transducer wire through the hole in the larger end cap, tying a loose knot it, and fitting it over the end of the smaller end cap provided protection for the soldered transducer leads and strain relief for the wiring. This probe (Fig. 3) picks up ultrasonic sounds without being highly directional or requiring physical contact, which is great for figuring out that you are in the general area of the problem. When I used this probe near the utility pole in question it detected weak ultrasonic noise, but it did not indicate ultrasonic noise at either of the other two utility poles in the area. Then I knew I was at the right pole and ready for the next phase, which was trying to determine where on that pole the arcing was occurring.

Fig. 4: Modified feedhorn/LNB with ultrasonic transducer installed.

Next I procured an 18” offset parabolic satellite antenna from a fellow ham. The idea was to use it as a highly directional ultrasound reflector. I removed the cover from the LNB and removed the small plastic piece that was located in the throat of the waveguide. I drilled a hole through the throat of the waveguide to facilitate feeding a wire through. Then I drilled a hole in the end of another PVC end cap and glued a transducer in that one. This time I used a scroll saw to trim most of the length off the open end of the end cap so that it was shallower. Quick setting epoxy was then used to mount this transducer assembly in the entrance of the LNB waveguide/feedhorn (Fig. 4.) Since the LNB was already mechanically aligned to be in the focal point of the parabolic satellite antenna assembly, I now theoretically had an ultrasonic transducer assembly that was positioned likewise. When this directional ultrasonic dish/transducer assembly (Fig. 5) was tested, it turned out to be *extremely* directional and capable of picking up the ultrasonic sound from lightly rubbing your fingers together from a distance of 20’ to 30’. Then I recruited the same ham radio buddy to stand about 50’ away from the reflector/transducer assembly and squeeze an empty nasal spray bottle which was taped to the top of a camera tripod in order to keep its location stationary. Doing so produces low volume ultrasonic sound as well as the audible “hiss” our ears can normally hear. This allowed me to aim the dish/reflector for maximum meter reading with the ultrasonic amplifier/converter. It is somewhat fascinating that you can stand right in front of this dish with the ultrasonic detector and shout into it without the ultrasonic amplifier/converter picking up anything. But rub your fingers together even lightly in front of it and you will quickly discover if you have the volume on the amplifier turned up higher than you realized.

Fig. 5: Completed directional ultrasonic reflector, with a couple of coats of black paint applied.

Once this was done, I located a couple of points on the repurposed satellite dish and LNB to use as a “sight” of sorts. Moving the dish around and then aiming it using the sighting points yielded maximum level and confirmed that it was indeed very directional -- aiming two to three inches to either side or above or below the ultrasonic sound source dropped the meter reading considerably or made it drop off to nothing.

With this amazingly directional ultrasonic detector ready for use, we made a final trip down the street to the utility pole in question. Checking from three different vantage points, it pointed directly to a lightning arrester/surge diverter (see Fig. 6.) I contacted the local power company and told them about the problem and how I had narrowed it down to a possibly faulty MOV lightning arrested/surge diverter. They very promptly sent out a crew who noted that the ground wire which attached to the bottom of the arrester/diverter, leading over to the side of the pole, and down the pole into the ground was positioned closer to the t-bar on which the arrester/diverter than the manufacturer recommended. This situation is known to occasionally lead to arcing between the ground wire and the portion of the t-bar near the diverter. They rearranged the ground wire, which was definitely an easier and quicker fix than having to kill the 7,200 volt line, which would be necessary in order to change out the arrester/diverter. Then they called asking me to go back and check to see if that had indeed solved the problem. The ultrasonic noise previously heard on the pole was totally gone. But even better, back at the shack there was no longer any discernible arcing noise or RFI. My HF noise level was S1, sometimes dropping to no indication whatsoever on the meter of my Icom IC-7200. I have never enjoyed such quiet conditions on HF at my QTH.

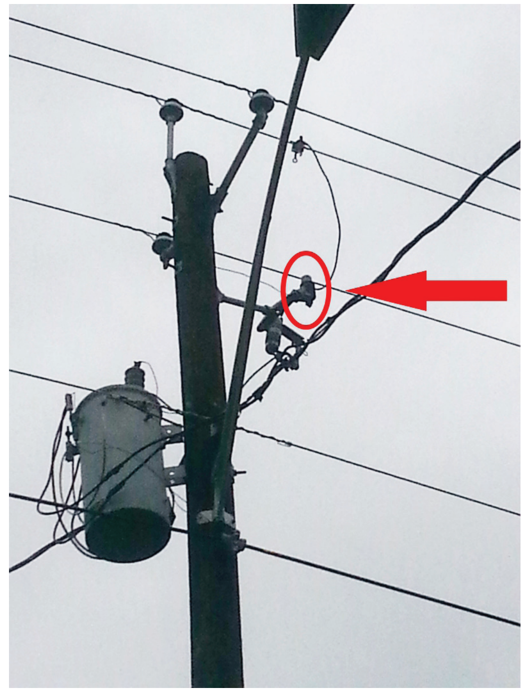

Fig. 6: Suspect lightning arrester/surge diverter, which the directional ultrasound reflector/transducer pointed to as the arcing source from three different vantage points.

The performance of this ultrasonic RFI chasing system I put together has been amazing. Excitement among fellow hams about this system has been surprising as well, with lots of inquiries regarding how I came up with this whole thing and built it, to wit, this article. Our local power company now knows they have a resource they can call upon in the event of an RFI complaint, saving them time and manpower, since they will not have to employ hit-or-miss tactics to try to locate and clear up arcing RFI problems, and they will not have to chase down a $50K+ infrared camera which might or might not detect the problem. My system can pinpoint the source of power distribution system arcing as well as very expensive systems manufactured and specially marketed for the same purpose, but I managed to put it together for a small percentage of the price tag of one of those packages. Even better, as a result of this project I now also own a system which can detect air leaks in hoses, tanks, etc., locate poor seals in windshield and window gaskets, etc., detect freon leaks, point out bearings in need of maintenance or lubrication before they actually fail, and much, much more. Like most hams, I love it when a project works, and I love it even more when it works better than hoped, costs less than expected, and does more than one job.

~ 73 from KK4ICE, who is presently enjoying some awesome DX'ing.

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