1+1+1 = 3 (Sometimes)

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Over the past several months the radio station I work for has been building a new studio facility. This is a totally new portion of a building, built to our specifications. Most of the equipment is also new. This has taken up most of my time, making it impossible for me to have time to write for this publication. On the other hand, it has given me quite a few ideas that will appear on this pages in the future.

One of the more interesting problems we have encountered during this project involved one of our consoles. First, some background.

The station I work for is a classical music station in a major city (if you must know which one, look at the credits). In addition to playing pre-recorded music, we also produce and distribute a number of programs for use by other stations. One of the mainstays of our facility, for years, has been a music performance studio. When we elected to move, it was decided early on that we should have such a space (bigger and better if possible) at our new location. In order to use such a studio we need a large recording console. This console is the one we are discussing in this article.

After the construction was completed we began installation of the equipment, one room at a time. When the wiring for the control room that services the performance studio was complete, we began to check everything out. The console was new and had been fully tested at the factory before delivery, so we expected that the only problems we would find would be some random errors in the interconnecting wiring. As we began testing, we noticed that the hum level of the console was considerably higher than anticipated. As we began to eliminate possibilities, we found that the hum was present when no faders other than the master were open. We immediately began to suspect either a problem in the console or a grounding problem.

We designed the facility with an eye toward providing proper power and grounding to eliminate or reduce hums and ground loops. Power was separated into utility and technical supplies. The utility power is for lights and convenience outlets and is derived from the three-phase mains in the normal manner, with every third breaker working from the same phase. The technical power has its own step-down transformer; the primary is three-phase and the secondary is 110 volt single phase. All outlets on the technical power have isolated grounds, with a separate #10 ground wire feeding a ground buss at one point only.

To check out the problem with the console, we began disconnecting everything from the console that was possible. We finally had nothing connected to the console but the test equipment. We made sure it was plugged into the same outlet and tried every grounding trick we could think of. Nothing made any difference.

We took a break, and when we came back the hum was gone. Further testing would not make it return. A while later, with no warning and no inducement from us, the hum returned. Then, because we had no better idea, we tried plugging the console into the utility power. Surprise! The hum level went down, but was not gone. This was an improvement but it wasn't right.

We called the console manufacturer and they sent out a technician to look at the console. He tried a number of tricks, including replacing the output module, but nothing worked. We continued to investigate the problem, but nothing seemed to work. The hum would come and go when it wanted to, but we could do nothing to influence it. We even tried shielding the console with a large piece of steel, but nothing worked.

By now we had moved into the new space. The staff was in their offices. We had shut down the old facility and were operating from the new (albeit incomplete) facility. Time was rapidly moving to the day when we were scheduled to have our first live broadcast from the new studio and we still didn't have this hum problem licked. We were just about to the point where we would have to use it, hum and all, and deal with the problem later. Not exactly what we wanted to do, but probably better than nothing.

Then, as we were once again trying to see what was happening, the hum level changed right before our eyes. Out of the corner of my eye I noticed that someone had turned on the lights in the performance studio just as the hum level changed. While this wasn't much to work with, it was a start.

We made a study of the influence the lights had on the hum level. The lights in the studio are on four circuits. Each circuit contains nine to ten, 150 watt bulbs in ceiling fixtures. We did not put any dimmers anywhere in the studio, to eliminate the possibility of buzz generated by the dimmers. As we tried various combinations of the four circuits on and off, we found that different combinations created different but predictable hum levels. In fact, one combination of two circuits on and two off was just as good as having all the lights off.

This data led us to believe that the problem was somewhere in the wiring of those light fixtures. We investigated the electrical panel and found that one circuit was

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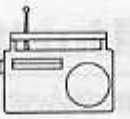

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on phase A, two were on phase B, and one was on phase C. Two circuits were on the first set of breakers and two were on the second set. When the two on phase B were on the hum level was as low as if none were on. We checked the circuits with an Amprobe clamp-on current meter. The current through the neutrals did not match the circuits that were turned on. We then checked a little further with the Amprobe and found that the *metal conduits* carrying the wiring for those lights registered over 10 Amps of current when the lights were on.

We then contacted the electrical contractor who wired the facility. This contractor is experienced in broadcast installations and recognizes the importance of proper grounding for audio and video equipment. When I showed him the results of our testing he confirmed that something was not right. In our conversation he indicated that this was more common that one would like, but would easily pass electrical inspection (it already had). When he checked it out, he found that when it was wired the neutrals were reversed.

The electrical codes allow for a common neutral for the three phases of an electrical panel. In other words each set of three breakers can have one neutral. You can get away with this because of the phase relationship of the three phases.

The total current through the neutral actually decreases as the current in the three circuits becomes more nearly equal. However, the neutral should be in the same conduit as the three hot wires. Since the current drawn by the hots is being returned in the neutral, the total magnetic fields should cancel.

In this case the neutral for the first set of breakers was in the conduit with the hots for the second set and the neutral for the second set was in the conduit with the first set. Since they were reversed, the magnetic fields would not cancel and current was then being induced into the conduit.

The conduits were connected to the structural members of the building and this was apparently creating hum everywhere. I am not sure exactly how this was all getting to the console, but reversing the neutrals corrected the hum.

Now that you have read this you are probably wondering what it all has to do with normal day-to-day engineering at a normal radio station. Perhaps nothing, but perhaps everything. First of all, if nothing else, this is a good example of diagnostic troubleshooting.

Yes we did have a lucky break by noticing that the lights were affecting the hum, but that only made the process faster.

A few specific applications:

1. Never assume that something will work right just because it is new or has been checked out by the manufacturer. In this case the equipment was fine, but we would not have known there was a problem had we not been checking out everything. Of course, someone would probably have noticed when it would have been the most embarrassing.

2. When you are looking for the cause of a problem, assume nothing. Had we assumed that the electrical wiring was right, we would not have found the problem.

3. Use every clue available, even though it may not make sense at first. The fact that the hum was lower on the utility power than on the technical should have told us to check out the electrical wiring more closely. We looked at the grounding, but didn't check the neutrals or hots. Had we done that we could have saved some time.

4. If you aren't familiar with the local electrical codes or the theory of three-phase power, learn it. Knowing how AC three-phase power works enabled us to find the cause of the problem. While our electrical contractor did not give us any problems, knowing the electrical codes would have given us some leverage had we needed it.

I hope this experience will help save you from wasting a lot of time on your next troubleshooting problem. RG