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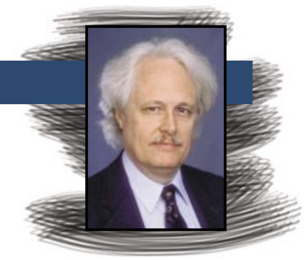
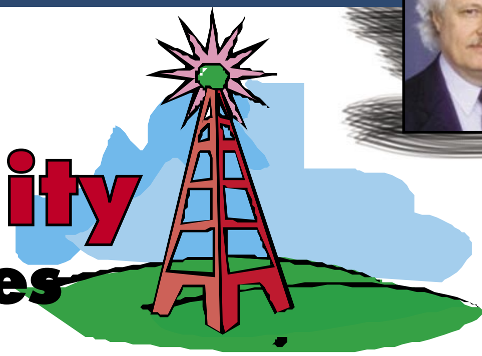
Random Thoughts from Chicago *by Jim Brown*



RF Susceptability in Microphones



In the last newsletter, we saw how RF voltage coupled onto the audio pair by SCIN combined with poor filtering at the inputs of audio gear could result in severe RF interference. [Repeat after me: “You say mic cable, Mother Nature says ‘antenna.’” (Neil Muncy)] We also showed how to test for that poor filtering, and looked at the results of testing some products with both good and bad RF rejection. This time, we’ll see how the outputs of audio gear a, and how to test for poor filtering at those outputs.

The circuit for testing equipment inputs used an RF signal generator to drive the shield of various lengths of balanced audio cable to inject RF onto the signal pair as a differential mode signal. This is a (very) rough simulation of the real world behavior of cables as receiving antennas in an actual installation. [Bill Whitlock has observed that this circuit can also inject some common mode RF.] See the previous newsletter for a discussion of how that circuit works. The same technique can be used to inject RF onto the balanced output terminals of a piece of audio gear. Figure 1 shows a test setup that I developed to test microphones.

The microphone test setup differs from the setup for testing equipment inputs in several ways. First, we need to connect our test equipment to the same circuit that we are injecting with RF. Second, the microphone requires phantom power. Third, the microphone must be preamplified so we can listen to it. Fourth, pin 1 must be isolated so that pin 1 problems do not pollute the measurement (that is, I want to separate pin 1 problems from poor filtering of the signal pair). Fifth, we need to keep RF off the measuring system so that RF susceptibility of the test equipment does not pollute the measurement (that is, we want to look at problems in the microphone, not the measurement equipment). And finally, we want all of the RF current from the genera-

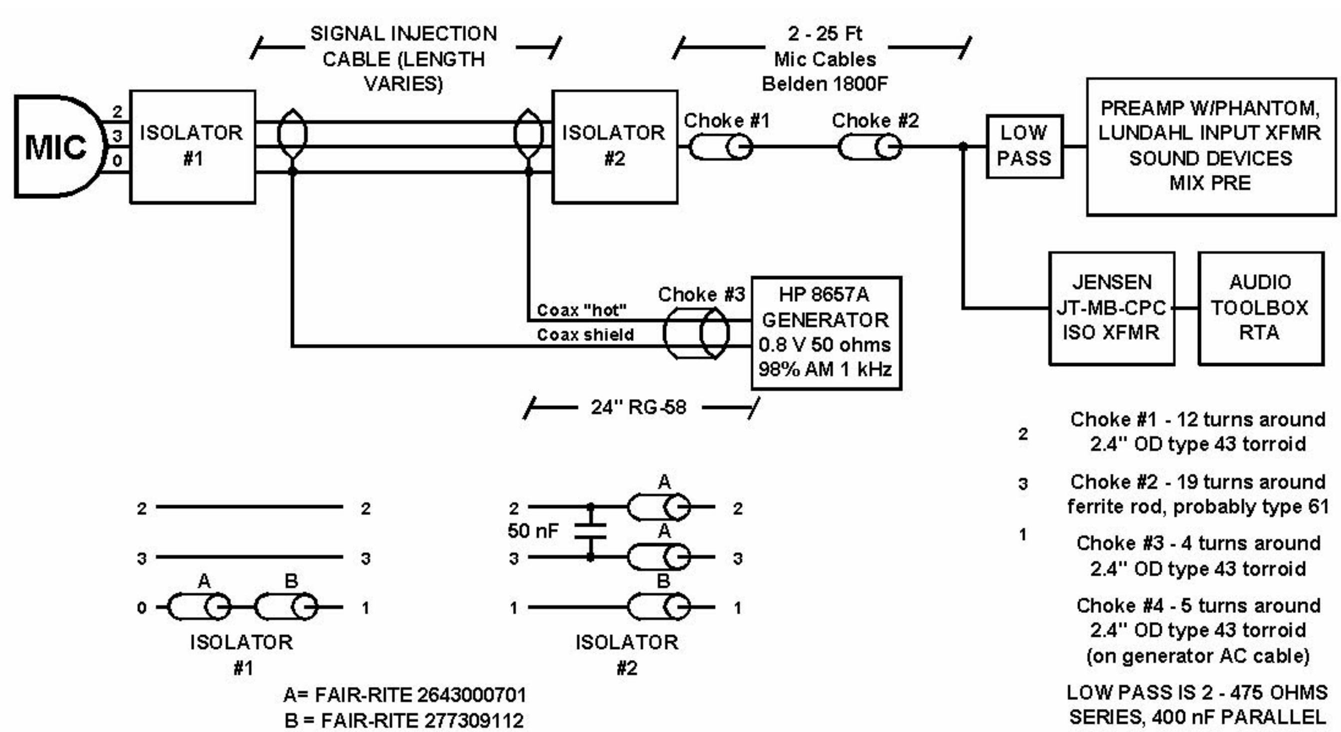


Fig 1 –Test setup for susceptibility of microphones to RF on the signal pair.

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tor to flow onto the cable shield, and none of it to flow to the mic or through the test equipment ground connection back to it's own chassis.

The isolation networks turned out to be much simpler than the one needed for pin 1 testing. First, pin 1 problems in the mic were eliminated by connecting the cable shield to the mic case and making no connection to pin 1. This also completed the path for phantom power. To make sure that no RF current flows to the mic enclosure or to the test equipment, ferrite beads were added around the shield connection to the mic, as well as to the shield of the cable leading to the test equipment. To further reduce common mode current from the RF generator back through the power supply of the test equipment, the mic cable running to the test equipment was wound around two large ferrite toroids to form RF chokes.

The 50nF capacitor that is part of Isolator #2 has two functions. First, it prevents RF from being coupled onto the signal pair of the cable leading to the test equipment. Second, it shorts the cable at the end opposite the mic, which causes any imbalance in the voltage induced on the two signal conductors by shield current (SCIN) to appear as differential mode RF on the signal pair at the microphone. See previous newsletters for a discussion of SCIN, pin 1 problems, and the rest of the test setup.

The test equipment is thus observing the output of the mic as it is subjected to the RF generator. When the test setup is working properly, no detected RF interference (1 kHz amplitude modulation from the generator) should be observed by the test equipment when a dynamic mic is the "Device Under Test" (DUT).

Figure 2 shows the susceptibility of a microphone that has good rejection of AM broadcast RF, but has mild susceptibility at VHF TV frequencies. This mic had moderate susceptibility to a ham transmitter on 14 MHz.

The mics whose data are shown in Fig 3 and 4 are from the same manufacturer. It is clear that these mics lack a good low pass filter at their output terminals (or that they have a low pass filter that is set to a frequency that is much too high). Both experienced moderate interference from the AM broadcast transmitter, and the mic of Fig 3 had problems with the ham transmitters at 1.8 MHz and 3.5 MHz.

This mic had no problems with AM broadcast or ham transmitters, but it was unusable anywhere near VHF TV or FM transmitters.

By studying these data and comparing them with field test results (described in earlier newsletters), it might appear that the test is much more sensitive than needed to predict interference. To have audible problems with differential mode RF, the RF detected in these tests would have to be more than 40 dB above the noise floor at AM broadcast frequencies, more than 20 dB above the noise floor at HF (3-30 MHz), and more than 40 dB above the noise floor at VHF (30-300 MHz).

At first glance, it might also appear that the field tests were much more stringent that they need to be, but that isn't true. The AM broadcast band testing was done within ½ mile of a 50 kW transmitting antenna, and the ham radio tests were about 20 feet underneath 100 watt transmitting antennas. In both cases, the acoustic noise levels were much higher than they would have been in

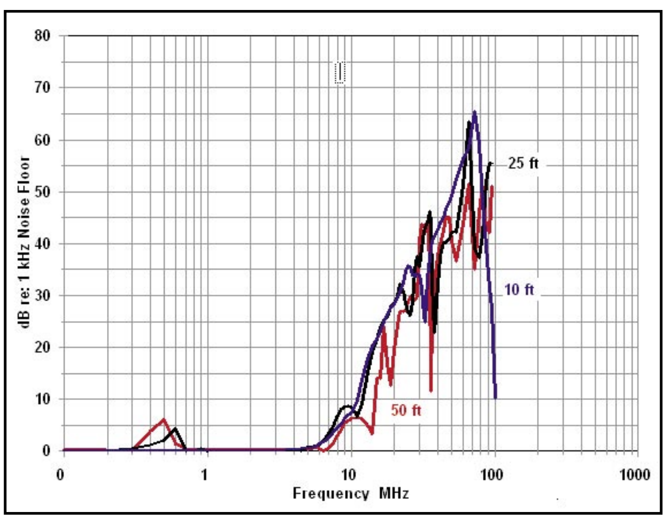

Fig. 2 – Differential mode susceptibility of a very good omni mic

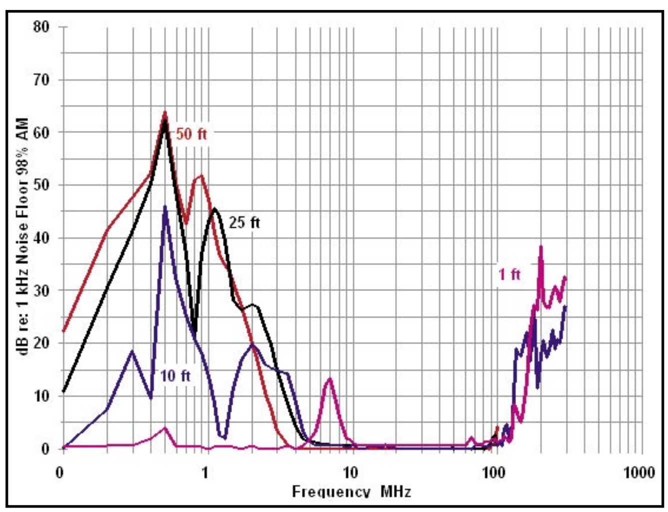

Fig. 3 – A mic with susceptibility to AM broadcast RF

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the churches, theaters, and studios where these mics would be used. In other words, the RF interference may be still be present, but is concealed by the high acoustic noise level of the test environment that won't be present in the studio or church. The difference in acoustic noise level is equivalent to being about ten times the distance from the transmitting antennas, or at 1/100 the transmitting power at the same distance, or 1/10 the transmitting power at 3.2 times the distance. Moreover, a very long mic cable might be a good enough antenna to put enough RF into the mics of Fig 7 and Fig 8 to cause audible interference.

And that's not all. When RF is detected at the input of a sound system, it is often detected at multiple inputs -- the detected audio is nearly always in phase, and is usually in polarity. Consider a mix console receiving RFI at multiple inputs from mics operating at equal gains relative to the acoustic signal. The sound picked up by these mics will typically add non-coherently – that is, 3 dB for each doubling of the number of mics at equal gain. But the RFI picked up by those mics will add coherently – 6 dB/doubling. Thus the audibility of RFI can increase by 3 dB per doubling of the number of mix inputs that receive the detected RF. That translates to 3 dB for two inputs, 6 dB for four inputs, 9 dB for eight inputs, 12 dB for sixteen inputs, and 15 dB for 32 inputs. In the real world, it's rare for all the mics to be "in the mix" at full gain, so 6-10 dB is probably a reasonable allowance for the coherent summation of sources in a typical large system.

Now that we understand these two major interference mechanisms, we can begin to think about eliminating interference when we encounter it. Certainly we could dig into equipment and modify it to fix pin 1 problems, and add the RF filtering that the manufacturer left out. More important, we shouldn't let manufacturers get away with building RF problems into their products – we should send them back and insist that they fix them (at no cost). No one can make money doing their own job and someone else's too. But what if we don't want to do that (or don't have time to wait for the fix)?

The path to the answer lies in realizing that the common factor in the two primary mechanisms, pin 1 problems and SCIN, is common mode current, especially shield current. So reducing or eliminating RF current on the shield would seem to be at least a partial solution to many RF problems. We'll concentrate on that topic in the next newsletter, but to get you thinking on the right track, I've got one word for you – FERRITES!

And this postscript. Since presenting this research at the Amsterdam and New York AES conventions, I've been approached by a half dozen mic manufacturers thanking me for publishing this research, and telling me that they have been hard at work on their microphone designs to correct these problems. I wish I could tell you that I've heard the same from equipment manufacturers -- but I can't.

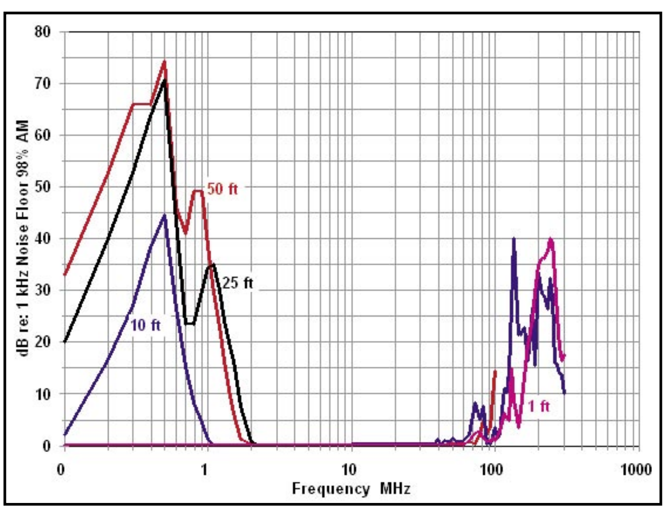

Fig. 4 – A mic with even greater susceptibility to AM broadcast RF

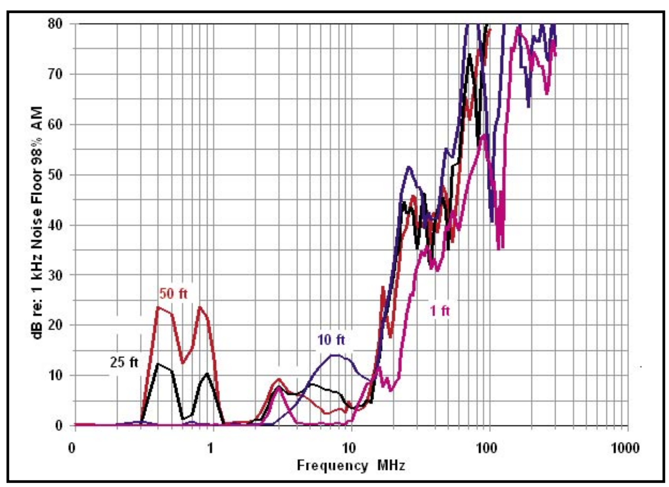

Fig. 5 – A mic with severe susceptibility to VHF RF.

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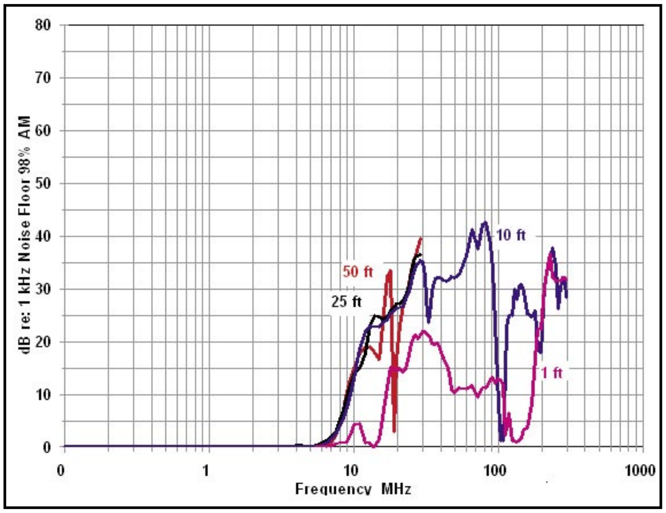

Fig. 6 – This mic experienced moderate interference from the ham transmitters in the 10-30 MHz range.

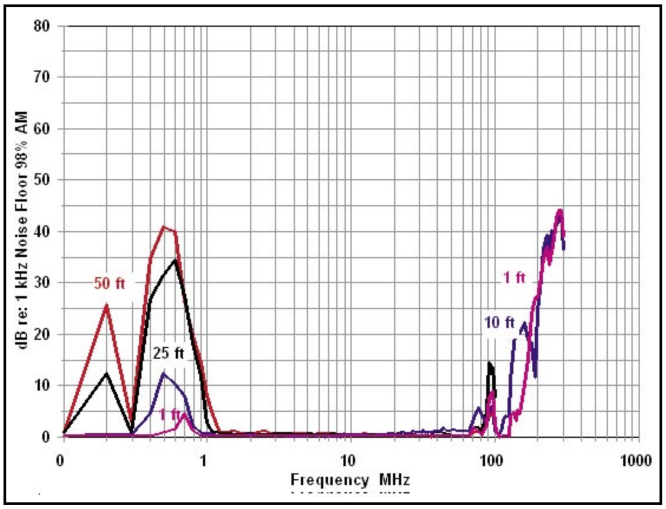

Fig. 7 – This mic has sufficient filtering to reject all but the strongest RF below 200 MHz. It experienced no interference from the AM broadcast or ham transmitters.

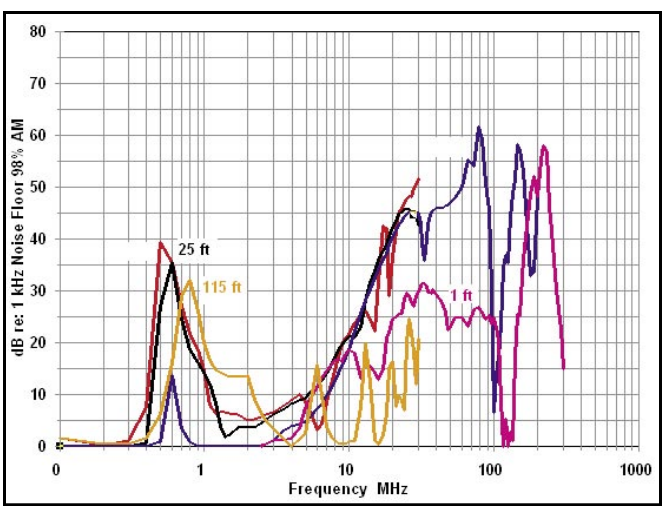

Fig 8 -- This mic had no problem with the AM broadcast transmitter, but it did receive interference from the ham transmitters and from some VHF TV.

70.7 Volt Systems *(cont. from page 25)*

an accepted distribution voltage (determined mainly by code considerations), and describes what would be measured if a sine wave were used as the signal (like the power company). Since we don't usually feed sine waves to loudspeakers, the measured voltage will vary. The typical value on the line would be 70.7V + 3dB = 100V-peak, less 10dB for the program material crest factor - roughly 30 VRMS or so. Also, if one assumes a sine wave and fixed load values, all of this can be described in terms of power transfer - hence the "wattage taps" on distribution transformers.

Some "Factoids" About 70.7V Systems:

1. The 70.7 volts is the RMS value of the largest sine wave that will "fit" through a 100VDC supply. Typical program material will have a much lower RMS voltage.

2. Any voltage could be used. Other "standard" choices include 25V, 100V, and 140V - all for sine waves.

3. If the voltage and impedance values are assumed to be fixed (they're not) then the signal transfer can be described using power rather than voltage or impedance. This makes it easier to keep track of how the amplifier is being loaded, but more confusing in that these power values are only true for the assumed voltages and impedances.

4. This whole distribution scheme can be described using a power model, voltage model, or impedance model. All three are included in Figure 1.

5. The impedance meter is the tool-of-choice for troubleshooting such systems, as it reveals the electrical impedance of the line including the effects of all loudspeakers, transformers, and wire. It effectively shows "what the amplifier is looking at."

6. When the amplifier's output voltage is ratioed to a higher value, so is the minimum impedance that it can safely drive. For instance, a "28V at 8Ω" amplifier becomes a "70.7V at 50Ω" amplifier with a step-up transformer.

Study the diagram carefully to see how the transformers affect the voltages, currents, impedances and power transfer. *pb*