# EMC FOR THE HAM SHACK

Steve Jensen - W6RHM *

## Overview

Traditionally, writings/presentations etc. regarding interference issues for amateur radio stations have focused heavily on harmonic reduction from the station transmitting equipment, installing low pass filters on transmitters and high pass filters on television receivers and other techniques that have come to be known as conventional wisdom with regard to this subject. With the proliferation of commercially built amateur transceivers meeting the "FCC standards for spectral purity" and the reduction in the popularity of "on the air" television, the ham radio operators are typically confronted with much different interference scenarios than in past years. This paper then is an attempt to review the mechanisms by which RF sources found in the ham shack can couple interference into other electronic devices possibly located in the neighbor's house via paths other than antenna to antenna coupling which has been so thoroughly studied in the past. Developing an understanding of these mechanisms will suggest some relatively easy techniques for reducing these effects.

## The Power Line - The Most Significant Thing You Share With Your Neighbors

As I look out the window of my ham shack, a power pole having four drops serving my house and three of my neighbors is evident. My house is on a corner lot and hence the pole located on the corner feeds the three other houses across the intersection as well as a line running further down the block serving at least two other houses on my side of the street. So in effect, each of these five homes is in parallel via the common tie point located just outside my ham shack window. If, by the activities in my house, common mode RF currents should be injected onto these power lines (Common mode current = Currents in phase on all conductors with respect to the earth ground) it is only reasonable to expect that my friendly neighbors will be in receipt not only of the 60 Hz differential mode power that they paid for (Differential mode = Current flows out of phase on each conductor with respect to each other) but the added bonus of the common mode RF current, that I may have inadvertently provided as well. Once having introduced this common mode RF villain into my neighbor’s homes, all manner of electronic atrocities may be observed to occur. A few of the common ones (by no means a complete list) include VCR control anomalies (my friend across the street's VCR went into rewind when I was on 20 meters), superposition of SSB audio onto various audio entertainment devices, and certainly upset various telephone answering machines and FAX devices. Unfortunately, the days are past where we could simply install a highpass filter on the neighbors TV antenna input and cure all of the electronic upsets that he might have experienced.

* 1601 Arcata Drive, Redlands, CA 92374

Common Mode RF on the Power in Your Neighbors House

Most electronic devices in use in the home today that utilize AC power, have some filtering on the AC power line input for the rejection of differential mode noise, transients etc., that may come down the power line. However, they usually have little or no ability to reject common mode currents entering via the power leads. The consequential effect is that the circuitry inside finds itself at elevated RF potentials with respect to the surrounding earth potential and any interconnecting leads going to other devices. An example of this situation is the VCR interconnecting to the companion television receiver. If the power leads of the VCR are being driven with RF voltages with respect to earth ground at one potential and the circuitry of the TV receiver is at another RF potential, the interconnecting cables between the VCR and the TV will conduct RF current in an attempt to equalize this potential difference between the two devices. Hence, we have a situation in which common mode RF is presented as an input to the TV receiver external video source input and the VCR video output and/or input. Because of the lack of common mode rejection of entertainment quality electronics at RF frequencies, rectification of the incident RF often occurs resulting in DC shifts on control and input leads. The effect results in chaos, frequently of the sort that turns the TV on and off, distortion of the audio and video etc. and indirectly leads to phone calls from the neighbors in which unkind references to your ancestry are sometimes made. The balance of this paper then is devoted to what can be done within the station to minimize the introduction of common mode RF current on the AC power leading to and from the Ham shack in the first place. The subject of improving the immunity of the neighbor's equipment to such effects is an entirely separate but important subject that has been well treated by others.

Transmitter to Power Line Coupling Paths

Probably the most important observation to make relative to the construction of your amateur transceiver is the shell of the coax connector providing the antenna output is hard grounded to the chassis of the transceiver. Moreover, if the transceiver has a built in AC power supply, there will be a safety "Green Wire" connecting the chassis of the transceiver to the third wire ground pin in the AC outlet. Within the conduit wiring is the two AC power leads (usually black and white for hot and neutral respectively) and the green safety wire leading to the earth ground rod at the power service entrance location. So if for whatever reason, there is RF voltage present on the chassis of your transceiver, it will drive the green wire directly which will couple to the other two leads in phase and result in common mode RF current flowing backwards out of your house and out to the neighbors. The following is a list of the most common mechanisms by which RF voltages are induced onto the transceiver chassis thence to the power lines by the mechanism described above:

Induced Common mode current on the antenna coax

This is not to be confused with high VSWR at the transceiver antenna terminals. If the antenna is coax fed, and the antenna end of the coax is a balanced load such as a dipole, conversion of the differential mode RF voltage present on between the center conductor and the shield of the coax to common mode voltage on the shield with respect to the earth ground will result as a consequence of the shield of the coax being driven by the unbalanced load. Hence, merely "tuning out" the VSWR with a tuner at the transmitter end of the coax will not help the problem with regard to RF induced on the power lines as the shield path from the transmitter to the tuner and the tuner to the antenna coax is not isolated (The chassis of each are all common through the interconnecting coax cable shields.).

The mechanical analogy to this problem is shown in the handout as a little like a rotating record on a turntable with the hole in the record being off center. The position of the hole in the analogous "record" is determined by the division of two vectors or "balance" corresponding to the magnitude of the impedance of each load connection with respect to "earth" potential. If a balanced load such as a dipole is driven directly with coax without a suitable transformer to generate a symmetrical drive, the "record" rotates about a hole near one edge instead of the center. The resulting "wobble" is analogous to the common mode voltage that drives the shield of the coax as a result. When the balance is "perfect" there is no "wobble" and hence no common mode current on the coax. Another analogy is to imagine a car whose wheels are all mounted to their respective axels with the axel off-center. Yes you can still deliver power to the road but on a once around basis the road delivers power back to the car creating major “bumping”. It is this “bumping” that is the mechanical equivalent to connecting a balanced antenna load directly to the output of an unbalanced transmitter source such as a 50-ohm output.

<u>Unbalanced Antennas Operating With respect to Earth Ground</u>

Such antenna systems must always be driven in such a manner so that the transceiver source is common mode isolated from the earth ground return to the antenna. Otherwise the chassis of the transceiver is at a voltage division point between the actual earth ground point of the antenna system and the radiating element of the antenna. Ground wires to the transceiver chassis do little or no good because of their significant inductive reactance at RF frequencies. (I.E. an 8-foot long wire is an open circuit at 10 meters!) The following two sketches illustrate this point.

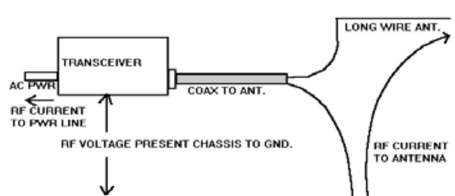


FIGURE 1 - UNBALANCED ANTENNA SYSTEM NO ISOLATION - HIGH CM RF CURRENT TO POWER LINE (BAD)

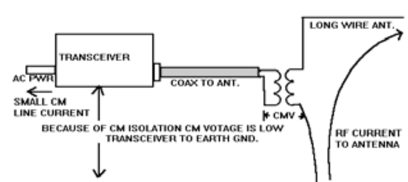


FIGURE 2 - UNBALANCED ANTENNA SYSTEM WITH ISOLATION - CM VOLTAGE PRESENT AT XFMR NOT AT TRANSCEIVER CHASSIS (GOOD)

<u>Antenna Structure Too Close to Power Lines</u>

This one is obvious, I expect. When placing the tower or antenna structure, pay attention of the proximity to overhead power and most important, proximity to the power leads feeding your house! If your dipole parallels the power feed to your house at a distance of 5 feet away, you may be sure that there will be RF not only all over your house but your neighbors as well. If possible try to cross polarize the antenna system with the power feed to your house. This will reduce the coupling to a minimum and reduce all of the common mode effects resulting from the pickup. In this regard, vertical antennas are better from a cross polarization view as the power line drops are usually horizontal or nearly so. Rotary beam antennas are usually well above roof levels so coupling is minimized here as well.

## Things To Do In The Shack

Obtain a collection of 850 μ ferrite toriodal cores of various diameters. These are available from such firms as the FAIR-RITE Corporation (Type 43 Material) and Amidon Associates (Advertisement in QST). The largest standard diameter core is about 2.5 inches OD. This core is large enough to pass a conventional AC power cord, plug and all, through the center without having to commit surgery on the cord. Wrap the line cord from your transceiver and through the core such that one layer is formed only. Do not overlap the start and the finish. This is usually about 3 to 4 turns on the 2.5 Inch OD core. Position the core as close to the transceiver end of the line cord as possible. Do the same thing with all the coaxial cables leaving the shack as well as the cable between the antenna tuner and the transceiver. If you have a transceiver using 12 VDC power and an external power supply, wrap the 12 VDC power cable, all conductors together in the same manner. Again, position the core as close to the rig as possible.
The effect of these cores is to raise the common mode impedance of the conductors leaving the rig so that the common mode RF current leaving the shack will be at a minimum. Since it is usually not possible to obtain perfect balance on the feed system the common mode chokes will help open the loop that exists between the antenna system and the power line.

## Grounding

Remember, a ground wire serves little or no purpose at RF frequencies. It's main use is for safety and it is certainly a good idea to have an independent earth ground to the rig for that purpose in the event that the green wire is not connected properly or doesn't exist at all. Remember though that the coax cable to the antenna system should be earth grounded OUTSIDE THE SHACK. This is so that in the event of a lightning strike, you don't find yourself or your rig in series with a lightning stroke. If the recommendations outlined here are followed, the RF voltages inside the shack will be low anyway and the need for an RF ground will not be important. This should be of some relief for those folks attempting installations on the upper floors of multi-story buildings.

## Summary

A few relatively simple steps with regard to minimizing common mode RF currents from your transmitter/power supply/antenna system will greatly reduce the impact on yours and your neighbor's electronic devices that turned out to be unintentional radio receivers as an undesired optional feature. The compatibility issues will undoubtedly keep increasing in complexity with the advent of the totally "wireless" electronic era that seems upon us. As these devices continue to promulgate, the Ham community will likely face new challenges in an effort to keep the peace with the neighbors. To do everything possible within reasonable technical limits seems only fair. The ideas presented here cost a few dollars at most to implement and may well be worth the price in terms of peace of mind and good relations with the rest of the neighborhood.

**APPENDIX**

Mailing Address and Telephone Numbers for Ferrite 850 μ ferrite cores:

Fair-Rite Products Inc.
PO Box J
One Commercial Row
Wallkill, NY 12589

Their part number for the 2.5-inch OD core shown in the talk is 5943003801
Distributed by PSC Electronics, Sunnyvale, CA (800)-654-1518

D.M Steward Mfg. Co.
PO Box 510
Chattanooga, TN 37401

PH: (615)-867-4100
Their P/N for core shown in the talk is: 28T2401-000

I do not have information about distributors in the Bay area.

73,

Steve - W6RHM