

Grounding Systems in the Ham Shack Paradigms, Facts and Fallacies

Content provided by: Jose I. Calderon, DU1ANV - Makiling Amateur Radio Society (MARS)

Reprinted with permission of the author

Through the years, I have been hearing problems from fellow hams over the air, and even in personal eyeball communications, about how they can organize and implement a good and effective Radio Frequency Interference (RFI) free grounding system in their ham shack. Some of these problems I heard are in parallel to the same problems I experienced in my early years of this hobby. Most new hams who operated mostly in the VHF and UHF band enjoyed their operating until later when they upgraded to the HF bands, and problems immediately cropped up. The first time they pressed the PTT and start talking in front of the microphone, all active equipment in the shack went haywire. Panel meters went crazy, the power supply volt meter jumped up and down, and if he was unlucky, he may have got his first microphone bite to shock him by surprise if the base microphone case was metallic.

Organizing an effective grounding system in the ham shack requires the ham radio operator to address the two major aspects of grounding. They are:

- **First** - Compliance with electrical safety guidelines (electrical grounding system), and
- **Second** - Dealing with RFI in the shack (RF grounding system).

In general, most newcomers to Ham Radio do comply with the first aspect in the context of electrical safety but often neglect the aspect of reducing the excessive presence of RF energy within the shack. Many believe that complying with good electrical safety guidelines is enough to dispel other operating problems. Though seemingly true, this notion is in fact a fallacy. Some of the problematic signs and symptoms of poor RF grounding in the shack that degrade the quality and satisfaction of operating ham radio equipment are enumerated below:

1. Microphone bites (nasty RF shock!)
2. Gritty and or fuzzy audio modulation (Distortion)
3. Malfunction of electronic keyer (sending wrong characters)
4. RF shock when touching metallic objects within the shack
5. Power supply jitters (the regulated power supply becomes un-regulated!)
6. Crazy SWR meter readings
7. Desktop computer going crazy
8. PC Desktop monitor jitters
9. Fluorescent lamp flicker
10. Active TTL switch circuit going crazy (Turning ON-OFF-ON by itself)
11. Inactive panel meters of separate equipment moving on their own
12. When transmitting, a distorted audio is heard over the amplified speaker of the PC desktop.
13. Severe Radio Frequency Interference (RFI) to home appliances within the vicinity of the Ham shack.

All of the above are the major signs and symptoms of the presence of high RF voltages within the immediate vicinity of the ham shack when the transmitter is active. And these are all attributed to poor RF grounding. All conducting objects

will absorb RF energy through coupling and will re-radiate the same. One can say "But I have already a very good electrical ground!"..... Fact? Or fallacy?

If you experience any of the above problems within the shack, I am pretty sure that you are suffering from a plethora of grounding and Un-Grounded ham shack problems. Let us analyze some scenarios of grounding systems typically complying with good electrical safety but which are poor RF grounding systems. An anthology of a simple case scenario and a worst case are presented and the possible problems that may arise at the instance the transmitter becomes active.

Scenario 1 (Simple case paradigm)

This ham operator was a neat fellow. One day, he finally convinced the xyl to let him setup his own radio shack, away from the prying eyes and itchy fingers of the family kids. And so he built his own radio room on the ground floor of the home QTH. He arranged his equipment and built a good electrical ground system by laying out a heavy copper wire about 3 meters long just behind the neatly lined up station equipment. He decided to run the ground wire straight so that each equipment ground lug can accommodate a short flexible grounding wire to reach the ground bus. He did this to all of the station equipment with a very neat connection so that the individual grounding wires did not get meshed up and entangled. The remaining length of the ground bus was led outside to an effectively driven ground rod just outside, near the wall of the Radio room. This grounding setup looked like the one shown in Fig. 1.

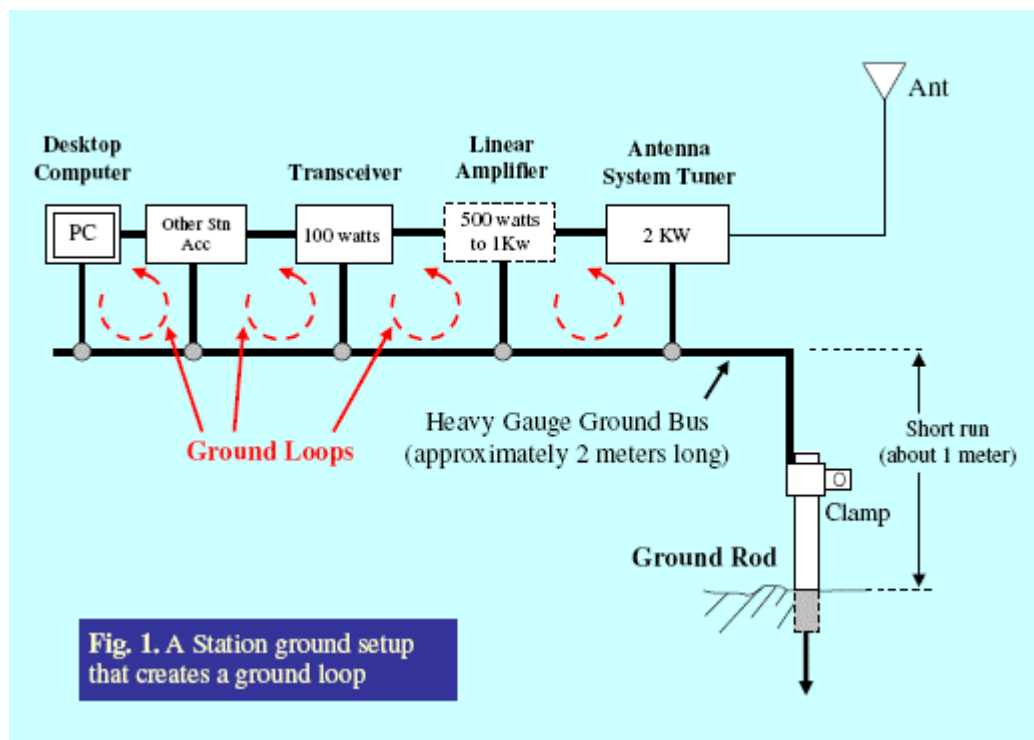


Figure 1.

When everything was in order, he fired the 100 watt transceiver and begun transmitting in J3E mode by calling another station at 7.035 MHz. To his surprise, the station operator at the other end responded to tell him that his signal was S9 but the audio was garbled, gritty and fuzzy. Further adjustment and tweaking the ALC and mic gain controls did not solve the problem. He further observed that by reducing the RF power to 50 watts PEP, the problem disappeared. But when he switched on his linear amplifier to give 250 watts PEP output, the problem returned and became even worse. The two stations spent almost two hours of

adjusting "this" and "that" but alas, to no avail. Just as our good and neat fellow ham was about to retire after a frustrating day, a third ham who has been monitoring the exercise came on frequency, and then politely said "You may be suffering from a "POOR GROUND".... The problematic ham answered "What?... I have a perfect ground system". He then described his new and neatly connected grounding setup"... "Hmmm..." said the third ham "You may have GROUND LOOPS! "...Then he proceeded to explain why. During the long QSO exchange, the problematic ham learned the following:

Ground loops are formed when the individual ground wires of each equipment are:

1. Ground loops are formed when the individual ground wires of each equipment are connected to the main ground bus at a point that is distant from each other (see Fig. 1)
2. The individual station equipments already have their own ground reference but when they are interconnected, grounding each equipment to the main ground bus as shown in Fig.1 creates GROUND LOOPS. Each time a ground loop is created, a small inductive coil is formed (the ground wire completes the loop).
3. When the ground loops are in the near field of RF energy (During transmit mode), these loops will couple to the RF energy (called RF coupling). As the RF energy is coupled to each loop, a fluctuating voltage is induced in unison with the burst of audio modulation of the RF energy. This energy will flow within the system and will seek the least resistance by following the associated circuits and eventually creeping into other internal circuits.
4. Once the RF is inside these circuits, it will interfere with the normal operating parameters of sensitive circuits thereby creating havoc. RF bleed-over escaping from long interconnecting coaxial cables may also flow within each loop, bathing the whole shack with RF energy.
5. His new ham shack has an excellent DC electrical ground system but has a VERY POOR RF GROUND SYSTEM!

Finally, the Elmer suggested to him to try the following:

1. Dismantle the present ground wire configuration.
2. Remove the long ground bus and terminate all ground wires from each equipment into a single point near your ground rod.

The problematic ham scribbled quickly in a piece of paper and came up with a final wiring that looked like the circuit shown in Fig. 2.

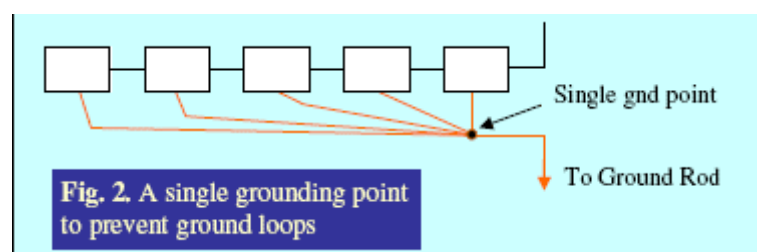


Figure 2.

They both agreed on the modifications and promised to contact each other at the same time the following day and then signed off.

Came the following days contact, the problematic ham called the Elmer and got an immediate reply. "Hey ol' man", the Elmer said, "you have a beautiful signal,

clean and kicking!" After a short pause came a reply... "Yeah thanks!" They exchanged an extended pleasant QSO and finally parted. The audio problem was solved and he was happy ever after.

Scenario 2 (Worst case paradigm) - The Un-grounded Ground

One day, during the next several rag-chew sessions on the same band, a third station joined the QSO. His signal was strong but the audio was also thin, fuzzy and garbled every time he raised his voice over the microphone. RF was all over the ham shack. He told the Elmer that every time he spoke over the microphone, the voltmeter of his regulated power supply jumped up and down the scale. The screen of his computer became fuzzy, and his lips were bitten with electrical shock if they touched the metallic case of the microphone. One night, while working a DX QSO, his Xyl came to the shack to give him the regular good night kiss. Holy cow! She and he received a mild electric shock the moment her lips touched his ear lobe! Also, he was threatened several times during the early evening QSO sessions by marble sized stones dropping and rolling down his roof top apparently thrown by close neighbors irked by the RFI to their TV, stereo and radio sets. Each time he transmitted, his Donald duck's voice was heard over their radio sets.

He told the Elmer that he was monitoring silently (Just reading the mails, so to speak) the previous exercise (In scenario 1) but did not bother to break-in so as not to disrupt the lecture over the air. Nevertheless, he told the Elmer that he followed to the letter the previous over the air advice but still his station suffered from a serious RFI problem within the shack. After describing his grounding setup, the Elmer said, "Aha! You have an ungrounded ground!" In a quick response, the third ham said, "What?... But I have a ground!". While listening meantime to the surprised ham, the Elmer drew in his mind the setup as described. This ham had his shack installed on the second floor of the house. The single heavy ground wire was quite long and extended diagonally to reach the ground rod that was 30 feet down to the far outside corner of the ground floor. His grounding system looked like the setup shown Fig. 3 below:

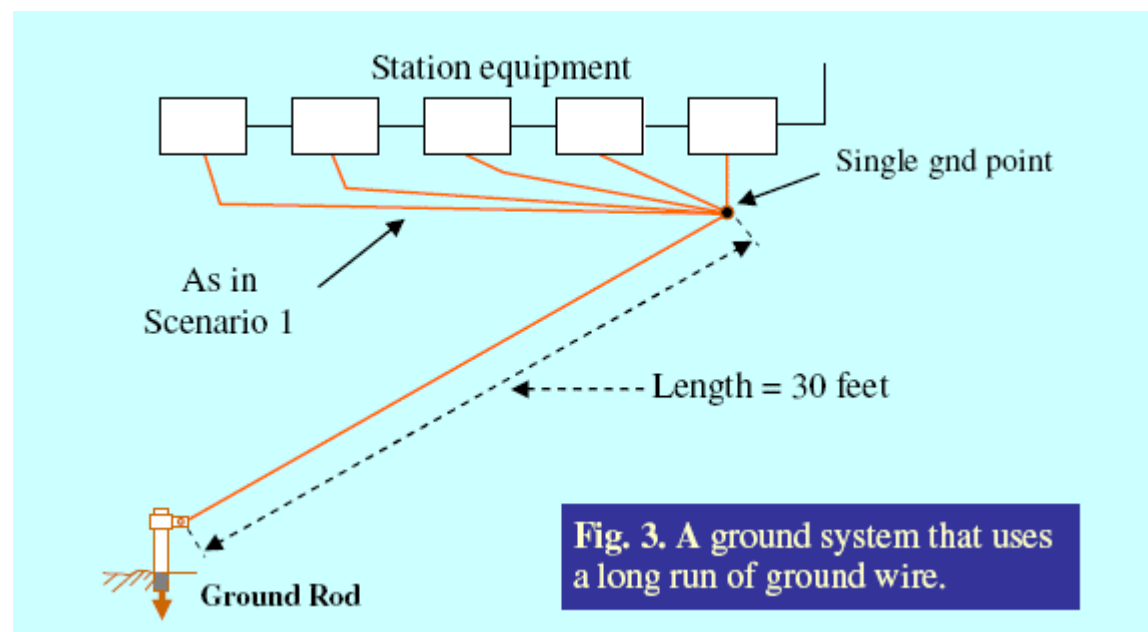


Figure 3.

In the next "over", the Elmer said, "It will take us quite long to discuss the reason why you have an ungrounded ground system. I suggest that I will send you a quick E-mail"..... When it comes, please read carefully and understand the explanations.... Asked his E-mail address, and then said 73....

The troubled ham received indeed the much awaited E-mail. Like a snorting bull, he retrieved quickly the attached document and begun reading the contents. The attached document read:

Dear troubled ham,
Further to our previous QSO, herewith please read and understand the explanation why your grounding setup is UN-GROUNDED! To understand why, please examine the drawing of its electrical equivalent circuit as shown in Fig. 4 below:

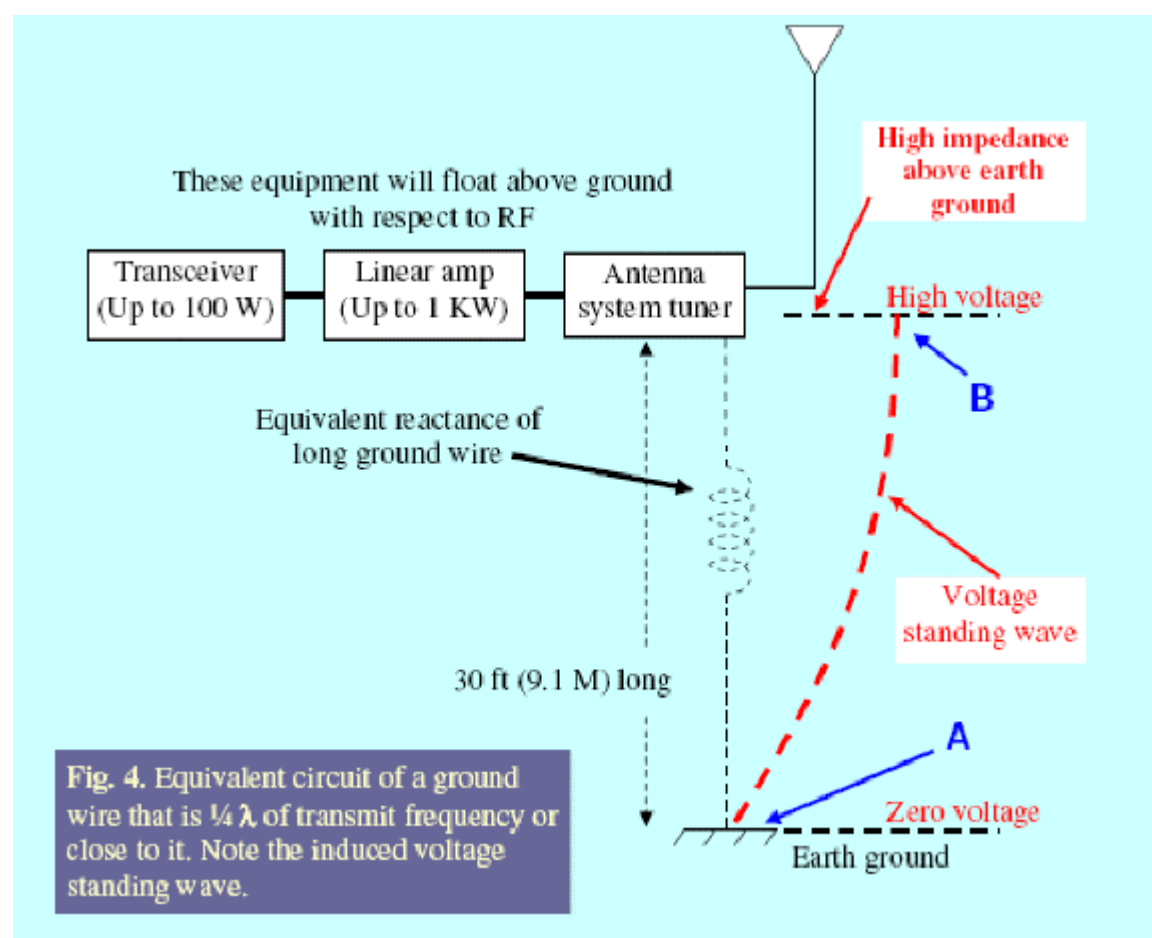


Figure 4.

The Elmer continued

Your ground wire is 30 feet long (9.1 meters); this length is very close to a quarter wavelength at 7 MHz. When you start transmitting at this frequency, your transmitter setup and antenna system will create an image of standing wave throughout the length of this wire. This is by virtue of the RF voltage induced due to resonance. If the long ground wire is $\frac{1}{4}$ wavelength long at the transmit frequency, this wire will resonate and will act as a radiating element. If the ground wire is less than a quarter wavelength, it will appear as an inductive reactance, the value of which is "Zero" (point "A") at earth ground and "High" at

the circuit ground point of the equipment (See Fig. 4, point "B").

If the wire is exactly $\frac{1}{4}$ wavelength of the transmitting frequency, the ground wire will act like a resonant LC circuit with very high impedance at its top (point "B" in Fig. 4). This reactance will appear like a resistance (called Impedance) to impede the flow of RF current to earth ground, bringing the ground return of all the station equipment to float above the earth ground as if the ground wire is not there (or, as an insulator at RF). Since one end of the wire leads directly to earth ground (Zero Impedance), it follows that the top of this wire (at the circuit ground point of the equipment marked as "B") is the high impedance point (High Z). The voltage standing wave that appears at any point along the length of this wire at the resonant frequency is:

$$E = \sqrt{P \times R} \quad \text{or} \quad E = \sqrt{P \times Z}$$

Where:

E = Voltage P = Power of transmitter Z = Impedance (if AC)

R = Resistance (if DC)

Now, as we go back to antenna basics, and reviewing Mr. Ohm's power formula as shown above, the voltage that appear at point "B" will be determined by the following parameters:

1. The power of the transmitting equipment.
2. The equivalent impedance value at point "B".
3. The length of the ground wire in wavelengths.
4. And, the extent of RF to earth ground leakage existing in the whole setup in the shack.

For calculation purposes, let us assume that there is a ground leakage (Equipment ground to earth ground). Due to the condition of the shack (furniture's, operating table, concrete floors and walls etc...all these are somewhat touching earth ground), the impedance at point "B" is for example equal to 1000 Ω . Then, the induced voltage at this point when the active transmitter output power is 100 watts, will be:

$$E = \sqrt{100 \text{ watts} \times 1000 \text{ ohms}}$$

$$E = 316.2 \text{ Volts rms}$$

Hmmm.... That's the reason why you have RF in the shack! Because you have an " RF UNGROUNDED GROUND! Hi hi...."

Of course this is true only if a ground leakage is present. If there is none, during the dry season for example (where moisture and humidity is nil) will aggravate the situation. The impedance at the top of the ground wire will increase somewhere to 1500 Ω or thereabouts. Therefore, under this condition and by interpolation, the voltage at point "B" of your setup will be

$$(316.2 \text{ Volts}) \times \frac{1,500 \text{ ohms}}{1,000 \text{ ohms}} = 474.3 \text{ volts rms (very high!)}$$

Below (See Table 1) are the voltage standing waves that develop at point "B" if you use different lengths of ground wire and, if the same parameters exist in your shack. The voltage values were calculated by interpolation using the wavelength factor.

Power Output of Transmitter at the antenna terminal of the system tuner					
100 Watts at 7.035 MHz			500 Watts at 7.035 MHz (Linear amp)		
Length of ground wire	Wavelength (equivalent)	Volts rms at Point "B" (standing wave)	Length of ground wire	Wavelength (equivalent)	Volts rms at Point "B" (standing wave)
10.1 meters	$\frac{1}{4}$ (or 0.25λ)	351.3	Same	Same	785.6
9.1 meters*	0.225*	316.2*	Same	Same	707.1*
3 meters	0.074	103.9	Same	Same	232.5
1 meter	0.024	33.7	Same	Same	75.4

* Your present grounding setup


 RF un-grounded danger zones

Table 1. RF voltage standing waves that are developed at point "B" (See Fig. 4) when lengths of ground wire are equal or less than $\frac{1}{4}\lambda$, at operating frequency.

Table 1.

You are living in an extreme RF environment! You are lucky that you and or any of your family are not wearing a "pacemaker". Otherwise, %\$#@#! You are somewhere in the fields of ambrosia by now! That level of RF in the vicinity of your shack will create havoc within its reach. Your own safety and the whole gamut of station equipment will be affected. Note also that whenever you increase transmit power, the voltage standing wave at point "B" will also increase!

Of course, the above exercise in Table 1 is true if the actual impedance at point "B" is 1000Ω. Other impedance values will give a result of voltages other than those shown. Any load connected at this end will change the impedance value but the voltage ratios between the short and longer wires will remain the same. Bear in mind that the impedance at the open end of a $\frac{1}{4}$ wavelength wire is about 2000-3000Ω. The example above is based on these assumptions but it will approximate the actual values. In these calculations, the power transfer loss was not considered to simplify the example and emphasize the voltages so created.

Also, if there is a wide mis-match between the antenna feed point impedance and the transmission line, a high voltage standing wave will result to a high VSWR at the antenna system tuner output terminal. This standing wave will aggravate the situation because this voltage will add up to the already existing standing wave created by the long ground wire. The result is catastrophic!. RF is all over the place.....

My recommendations:

1. Relocate the ground rod to be nearer to the shack so that the ground wire will be as short as possible and will not resonate.

2. Use a short length of ground wire that will not be $\frac{1}{4}$ wavelength (or its odd multiples), or close to it, of the operating frequency. This is also the reason why your transceiver manual recommends not using this length of ground wire!
3. Install the ground wire so that it will be far from telephone lines and main house wiring to prevent coupling of residual RF energy.
4. Relocate the ground rod and drop the ground wire through another location to be as far as possible from your close neighbor.
5. Match your transmission line impedance equal to the feed point impedance of the antenna or as close as possible to reduce VSWR at the tuner's output terminal (Take note: not the input terminal of the tuner! Because all tuners measure only the VSWR at the transceiver side)

I look forward to hearing your signals soon.....

73s...

The Elmer

Three days later, and during the next weekend rag-chew, the troubled ham reappeared on frequency. The Elmer acknowledged him with this comment; Hey ol'man! Your signal is fantastic with booming audio. Crystal clear! What did you do this time? After a short pause, the troubled ham answered.... Yeah I have a new friend! Who? The Elmer asked. The troubled ham said.... my close neighbor! Many thanks hi hi! I followed your recommendations! They all continued the round-table QSO and happily exchanged notes. The Elmer learned that this ham had eventually relocated his ground wire, the length of which is now only 3 meters long. It was still a little bit long but the power supply jitter was gone and the RF bleed-over to the microphone circuit disappeared when transmitting at 100 watts PEP. The Ham was elated and thanked again the Elmer.

Addendum

Dealing with high RF in the shack has no simple answers but the paradigms exemplified in the above scenarios presented the basic concepts and remedial solutions to a seemingly perfect grounding system. Most new comers in ham radio forget the basic fundamentals of radio and the behavior of physical entities within the ham shack when exposed to RF environment. Forgetting the basic fundamentals and failure of the ham to apply these principles and fundamentals to actual practice predisposes poor safety practice, danger from exposure to high levels of electromagnetic radiation and destruction of equipment and other station accessories due to poor RF grounding techniques. That power supply in the worst case scenario will self destruct eventually due to the presence of high levels of fluctuating RF leaking into the sensitive regulator sensing circuit. Due to poor regulation, the transceiver will follow to say "goodbye". The scenarios presented are extreme examples of real life experiences in ham radio practice. The two paradigms presented the basic problems and how to deal with each to reduce the presence of high RF levels in the shack. To exploit the complete elimination of RF down to zero levels will be a great feat, if not impossible, but reducing the RFI to such levels that will not interfere with sensitive equipment and circuits is enough to ensure safe and complete satisfaction to a continuing hobby.

The notion of having a good electrical DC ground return is enough to ensure safety in Ham Radio is a fallacy. This was consistent in the scenarios presented where no provisions were considered to reduce the presence of RF in the shack. Of course, one can consider that the solutions presented merely reduces the possibility of coupling (the ground loop) and the reduction of high voltage standing waves due to the use of long ground wires (the un-grounded ground)

that are equal or close to a quarter wavelength at operating frequency. Perhaps several questions that will arise from the lessons learned in the two scenarios presented maybe anticipated as follows:

1. What if the troubled ham in scenario 2 cannot relocate his ground rod to be closer to the shack?
2. What other recommendations can the Elmer suggest if the ground wire cannot be shortened?
3. What if the RFI still persist after doing all the remedial measures recommended in Scenario 1 and 2?

These are good anticipated questions. Not all amateurs are lucky to have their ham shacks installed in the ground floor of their home QTH. Many are the so called "Cliff dwellers", meaning that their shacks are located in elevated floors, such as the third floor or higher in apartment buildings and condominiums. Such cliff dwellers may not have the benefit of shortening their ground wires towards earth ground. In spite of this situation, there are still effective measures to consider. Some of these are new and some are as old as the age of the ham radio world.

The Elmer is nowhere to contact this time but this author will take the opportunity to answer the first two questions. There are two effective alternatives. They are:

Alternative 1 - The Counterpoise

This grounding technique is as old as the age of Ham Radio. The use of this technique dates back as early as 1895. It is used more effectively when earth ground conductivity is poor. But since your antenna per se also needs an RF ground to propagate efficiently at that higher elevation above earth ground (the reason of which, is beyond the scope of this article but maybe covered in future articles), it can be installed to perform the two functions. That is, to provide an artificial ground for the antenna when elevated high above earth ground and, to keep RF away from the station equipment. The setup is presented in Fig. 5 below.

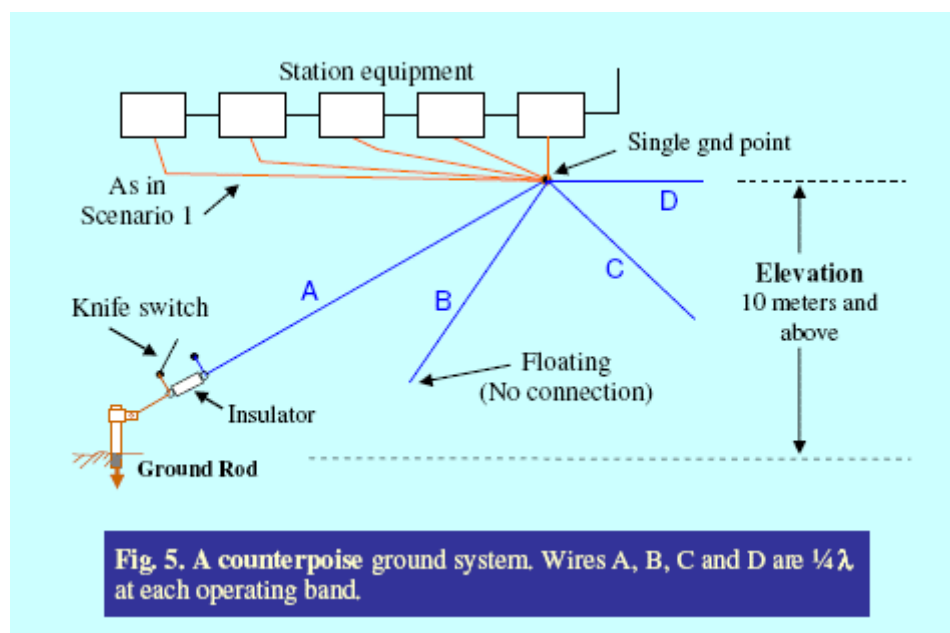


Figure 5.

Let us imagine that you want to operate on 4 amateur bands, namely 40, 20 15 and 10 meters. The installation procedure is given below:

1. Cut each individual counterpoise wire exactly $\frac{1}{4}$ wavelength of each operating frequency.
2. Connect one end of each to the single ground point terminal (see Fig. 5).
3. Leave all the opposite ends free and floating (no connection). For better efficiency, stretch and spread each wire in a radial fashion, away from the station equipment as shown in Fig. 5. The position and orientation of the wires is not however critical so that you may want to anchor each at the side wall of the apartment building (of course you have to insulate the ends by using small egg insulators). Another alternate is just to let each wire dangle downwards but still the wires must be spread out. How you will do it will depend on your prolific imagination.
4. Now, look for the longest wire (maybe the $\frac{1}{4}$ l 40 meter band counterpoise) that can reach the ground rod and designate this as your electrical ground. The idea is to use this wire to connect to your ground rod through a knife switch. When you are operating the station, the knife switch must be in open position. But when you stop operating and for safety reasons, you must provide an electrical ground. Run downstairs and close the switch. Remember however, to always open this switch whenever you sign ON the station.

The Principle of the counterpoise – In the older times, this contraption is used to complete the so called “Marconi antenna” which in effect is a quarter-wave antenna. In order to satisfy resonance, proper matching and efficient radiating properties, a quarter wave element is added to complete the antenna circuit. This is similar to today’s radial system that is installed in quarter-wave and $\frac{5}{8}$ wave antennas that are elevated above earth ground. We can use the same technique in keeping away RF from the station equipment. The electrical equivalent circuit is shown in Fig. 6 below:

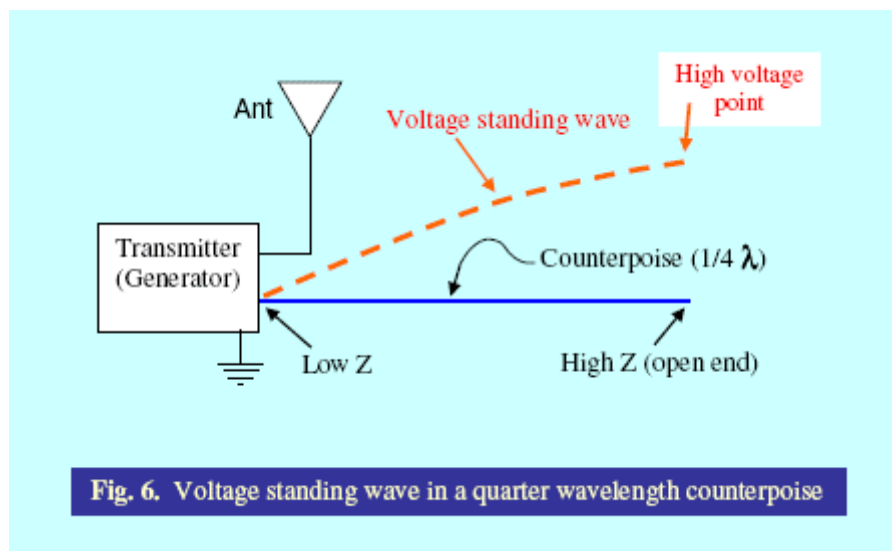


Figure 6.

The counterpoise is in effect an artificial ground. One end of the quarter wavelength is connected to the circuit ground of the system (RF generator or transmitter) and the other end is left floating. When the RF generator is active, an image of the signal is developed in this wire and a voltage standing wave is induced. The magnitude of this voltage is similar to a $\frac{1}{4}$ wavelength antenna at various points along its length. The open end of this wire is high impedance (refer

to antenna theory) while the opposite end that is connected to circuit ground of the generator is zero. It follows that the voltage at the generator side is zero (circuit ground) and the open end is high voltage.

Notice that the high RF voltage point is now the reverse of the voltage points developed in the case of scenario 2 (See Fig. 4). By taking advantage of this characteristic, the use of the counterpoise will shift the high voltage away from the station equipment. If each operating band has its own separate counterpoise, then each respective counterpoise will function as the operating band is changed, allowing multi-band operation and preventing severe RFI in the shack.

CAUTION! ---- The counterpoise wires will radiate RF energy. Make sure that the end of any of the wires will not extend near home appliances within your house and or near your close neighbors.

Alternative 2 -The RF Suppressor Ground System

This is the modern version of an ingenious device developed and introduced by several hams in recent years, notably by William Chesney/N8SA (See <http://www.hamuniverse.com/grounding.html>) who published the article in 2003. This grounding system addresses both the electrical ground and RF grounding requirements in Ham radio. The device is intended for long grounding wires. The grounding device utilizes a coaxial line where the ground wire is enclosed by a shield, such as RG-8 transmission line, to prevent the buildup of high voltage standing wave near the station equipment. This ground line is not length sensitive and can be used at any length without concern. It will keep out RF away from the shack. The wiring setup of this practical grounding system is shown in Fig. 7 below:

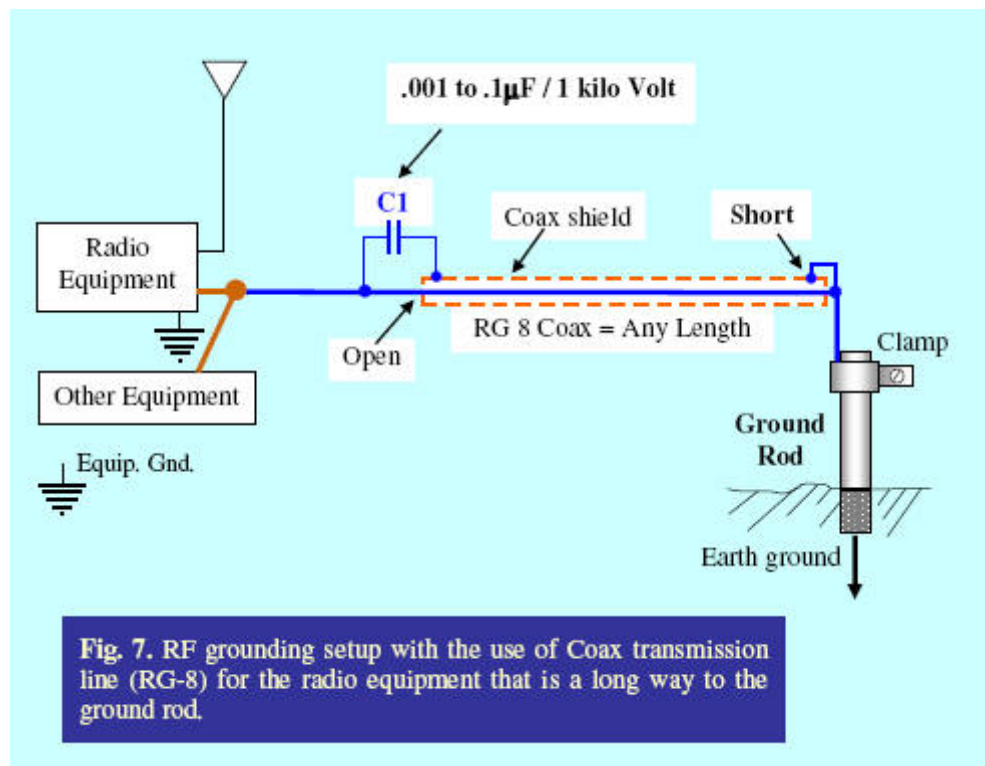


Figure 7.

Installation of the RF suppressor – Remove the existing ground wire and replace it with a length of RG-8 coax transmission line, enough to reach the ground rod and into the shack to connect to the ground bus. At one end, short (solder) the coax shield to the center conductor of the RG-8 and the remaining pig tail to be

connected (soldered) to a short heavy gauge solid copper wire to reach the ground rod (See Fig. 7). At the other end, strip the coax to reveal the center conductor and remove part of its shield. Connect the center conductor to the circuit ground of the equipment. Leave the coax shield open at this end but connect a ceramic disc capacitor (Marked as C1 = 0.001 to 0.1 μF / 1 Kilo Volt). One terminal of this capacitor is connected to the coax shield and the other terminal to the center conductor (See Fig. 7). The RF suppressor ground system is now complete.

Of course the capacitor value is selectable depending on the lowest operating frequency band and length of Coax. The correct value is selected until RF disappears in the shack (at the lowest band). Or, when your lips doesn't get to be burned or electrocuted (when touching the metallic mic case) as you speak or transmit. However, YOU MUST USE A HIGH VOLTAGE CAPACITOR RATING, about 1KV minimum, but the higher the better. Otherwise, ZAPPP!!!, this capacitor will explode if a surge of high voltage standing wave will develop instantaneously at or above 500 volts at this terminal.

The circuit shown in Fig. 7 is an effective RF grounding setup. The author's shack is in the second floor and uses the same grounding system which has been in use since 1989 with no RFI in the shack even when the 1 KW linear amplifier is in use. DU1FLA/Estoy uses the same grounding system. We used a .01 μF / 1Kv capacitor for C1.

Principle of the RF suppressed grounding system – By inspection (see Fig. 7), the ground wire is enclosed effectively by the coax shield so no high voltage standing wave can buildup in this wire. However, since the shield is exposed and floating, a high voltage standing wave will appear at the outer surface of the coax shield. This voltage is Zero at the shorted end (ground rod terminal) and high at the open end. When you connect a capacitor between the high voltage end of the coax shield and the center conductor (See Fig. 7), the impedance of this capacitor is very low at the operating frequency, thus acting as a low impedance load (By virtue of its low reactance = Z , in Ohms) between the shield and center conductor. The RF current will flow easily through this capacitor and is diverted to the center conductor enclosed by the shield and finally to earth ground. The buildup of high voltage standing waves between the inside surface of external shield and the center conductor is suppressed because the characteristic impedance of the RG-8 is only 50-52 Ω . And, the voltage drop across the external capacitor (C1) between the open end of the shield and center conductor is;

If C1 = 0.01 μF , then the reactance of C1 at 7.035 MHz is

$$X_C = \frac{1}{(2\pi) F \times C} = \frac{1 \times 10^{-6} \times 10^6}{(6.28)(7.035 \text{ Mhz})(0.01\mu\text{F})} = 2.26 \Omega$$

Assuming that the transmit power is 100 watts. Therefore, the voltage drop across this capacitive reactance (2.26 Ω) is;

$$E = \sqrt{P \times Z} = \sqrt{100 \text{ W} \times 2.26 \Omega} = 15.03 \text{ Volts rms ONLY!}$$

The combined parallel reactance of this capacitor and the total cable capacitance of the RG-8 transmission line will even decrease further the voltage drop. Also, as the operating frequency goes higher, the reactance of C1 will decrease. Hence, the voltage drop will be even lower. That is, as if the long physical length of coax ground wire is just about less than 1 meter long, electrically (See Table 1).

The voltage attenuation curve at higher RF operating frequencies above 7.035 MHz will in fact proceed at the rate of minus 6 dB per octave. This means, when the operating frequency is doubled (14.07 MHz); the voltage that exist across C1 will decrease to ½ the original amplitude. Further, because the center conductor of the coax line is connected directly to earth ground, it becomes automatically your electrical safety ground. How do you like that?

What we have presented and discussed dealt only on how we will keep out the troublesome RF energy near our equipment as far as ground loops and RF un-grounded grounds! But how we will make a good and effective RF earth ground to work with the antenna system during transmitting and receiving (Your system needs it whether you like it or not!) is another matter. In order to have an effective propagation for DX work requires a good RF earth ground setup. Merely having improved your equipment ground to earth ground is not a guarantee that you have also an effective RF earth ground..... Another fact!

Improving and or making a good RF earth ground to work with your antenna system is another topic that is not covered by this article. Similarly, to answer the anticipated question number 3 also requires a separate topic for another article. Dealing with numerous causes of RFI due to "near field effects" and gross exposure of ham equipment to high RF fields that are not caused by improper grounding systems, though somewhat related, is a separate subject. Available space does not warrant the extension of these topics but hopefully, these will be covered separately in future articles.

It is hoped that this article has enlightened the reader to understand the importance of effective grounding paradigms and, the facts and fallacies of grounding in ham radio. To make a shack RF free coupled with sound electrical grounding technique is a responsibility of the amateur operator to address the aspects of grounding when dealing with high levels of RF energy in the operating environment. Effective grounding of equipment is mandatory to address the issues of personal Safety, damage to sensitive equipment and prevention of severe RFI in the operating community.