Radio Frequency Interference!

Al Penney
VO1NO

Objectives

To become familiar with:

- The causes of interference;
- How to prevent and solve interference problems;
- How to deal with neighbours who believe you to be the cause of interference; and
- ISED regulations on interference.

Al Penney
VO1NO

RFI and EMI

- **Radio Frequency Interference (RFI)**
  - Interference to a **receiver** caused by **actual signals**, only one of which is desired.
  - Caused by harmonics, mixing, images, or poor design.
- **Electro-Magnetic Interference (EMI)**
  - RF Interference to a piece of equipment which is **not normally a receiver.**
  - RF gets into the equipment through **inadequate shielding, filtering, grounding or design.**
  - Affects **all sorts of equipment** – alarms, telephones, furnace controllers, smoke detectors, computers etc.

Al Penney
VO1NO

Electromagnetic interference (**EMI**), also called **radio-frequency interference** (**RFI**) when in the radio frequency spectrum, is a disturbance generated by an external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling, or conduction. The disturbance may degrade the performance of the circuit or even stop it from functioning. In the case of a data path, these effects can range from an increase in error rate to a total loss of the data. Both man-made and natural sources generate changing electrical currents and voltages that can cause EMI: ignition systems, cellular network of mobile phones, lightning, solar flares, and auroras (northern/southern lights). EMI frequently affects AM radios. It can also affect mobile phones, FM radios, and televisions, as well as observations for radio astronomy and atmospheric science.

Interference to consumer devices

Potential sources of RFI and EMI include: various types of transmitters, doorbell transformers, toaster ovens, electric blankets, ultrasonic pest control devices, electric bug zappers, heating pads, and touch controlled lamps. Multiple CRT computer monitors or televisions sitting too close to one another can sometimes cause a "shimmy" effect in each other, due to the electromagnetic nature of their picture tubes, especially when one of their de-gaussing coils is activated.

Electromagnetic interference at 2.4 GHz can be caused by wireless devices, Bluetooth devices, baby monitors and cordless telephones, video senders, and microwave ovens.

Switching loads (inductive, capacitive, and resistive), such as electric motors, transformers, heaters, lamps, ballast, power supplies, etc., all cause electromagnetic interference especially at currents above 2 A. The usual method used for suppressing EMI is by connecting a snubber network, a resistor in series with a capacitor, across a pair of contacts. While this may offer modest EMI reduction at very low currents, snubbers do not work at currents over 2 A with electromechanical contacts.

Another method for suppressing EMI is the use of ferrite core noise suppressors (or ferrite beads), which are inexpensive and which clip on to the power lead of the offending device or the compromised device.

Switched-mode power supplies can be a source of EMI, but have become less of a problem as design techniques have improved, such as integrated power factor correction.

Most countries have legal requirements that mandate electromagnetic compatibility: electronic and electrical hardware must still work correctly when subjected to certain amounts of EMI, and should not emit EMI, which could interfere with other equipment (such as radios).

Radio frequency signal quality has declined throughout the 21st century by roughly one decibel per year as the spectrum becomes increasingly crowded. This has inflicted a Red Queen's race on the mobile phone industry as companies have been forced to put up more cellular towers (at new frequencies) that then cause more interference thereby requiring more investment by the providers and frequent upgrades of mobile phones to match.

Two Issues for Hams…

- **Interference to others** caused by your station; and
- **Interference to your station** caused by other's equipment.

Al Penney
VO1NO

THE SCOPE OF THE PROBLEM

As our lives become filled with technology, the likelihood of electronic interference increases. Every lamp dimmer, garage-door opener or other new technical "toy" contributes to the electrical noise around us. Many of these devices also "listen" to that growing noise and may react unpredictably to their electronic neighbors.

Sooner or later, nearly every Amateur Radio operator will have a problem with interference. Most cases of interference can be cured! The proper use of "diplomacy" skills and standard cures will usually solve the problem.

Pieces of the Problem

Every interference problem has two components — the equipment that is involved and the people who use it. A solution requires that we deal with both the equipment and the people effectively.

Interference

- Any unwanted interaction between electronic systems.
- Four main types:
  - Noise;
  - Fundamental Overload;
  - Intermodulation Distortion; and
  - Spurious emissions.

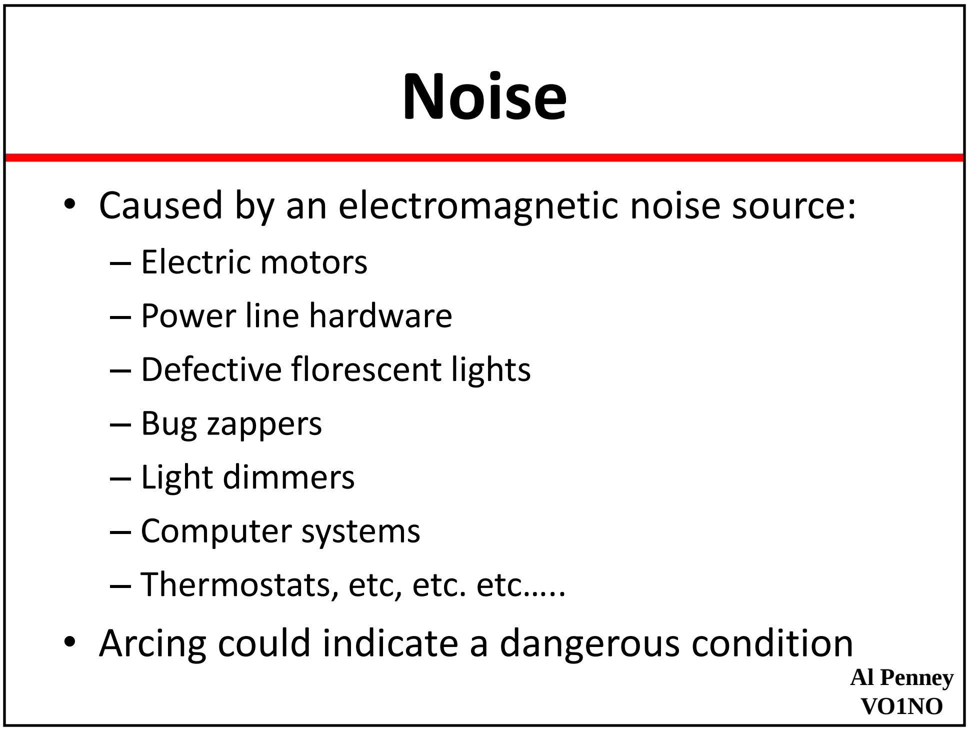
Al Penney
VO1NO

SOURCES OF EMI

The basic causes of EMI can be grouped into several categories:

- Fundamental overload effects
- External noise
- Spurious emissions from a transmitter
- Intermodulation distortion or other external spurious signals

As an EMI troubleshooter, you must determine which of these are involved in your interference problem. Once you do, it is easy to select the necessary cure.

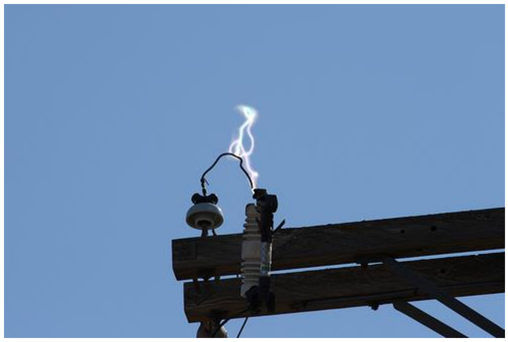


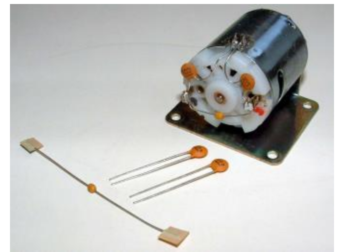
External Noise

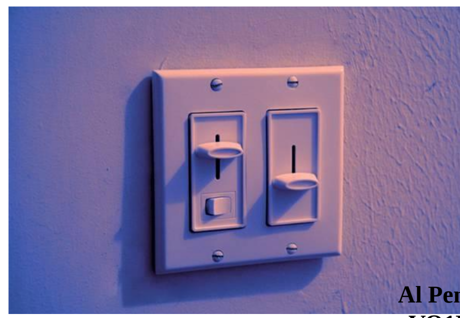
Most cases of interference reported to the FCC involve some sort of external noise source. The most common of these noise sources are electrical. External "noise" can also come from transmitters

or from unlicensed RF sources such as computers, video games, electronic mice repellers and the like. Typically, such devices are legal under Part 15 of the FCC's rules.

Electrical noise is fairly easy to identify by looking at the picture of a susceptible TV or listening on an HF receiver. A photo of electrical noise on a TV screen is shown in the TVI section of this chapter. On a receiver, it usually sounds like a buzz, sometimes changing in intensity as the arc or spark sputters a bit. If you determine the problem to be caused by external noise, it must be cured at the source. Refer to the Electrical Noise section of this chapter and *The ARRL RFI Book*.



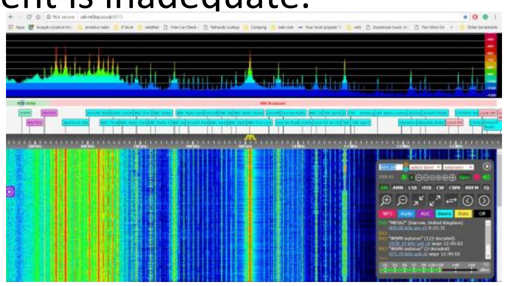




Al Penney
VO1NO

Fundamental Overload

- Caused by the inability of consumer equipment to reject strong signals.
- Even though your radio is transmitting legally, the filtering and shielding in the consumer equipment is inadequate.



Al Penney
VO1NO

Fundamental overload is a type of interference in a receiver caused by very strong signals. The very strong RF signals induce currents on receiver components, overloading them and making it impossible to properly process weaker signals received via the antenna. You may experience fundamental overload with your transceiver if another operator is transmitting very near your station on the same band to which your radio is tuned. Frequently this will produce loud and distorted audio from your receiver. So, fundamental overload may be a cause of radio frequency interference!

One challenging area of radio receiver design is that if achieving a good strong signal and overload performance whilst also maintaining a high level of sensitivity.

The overload performance is important because the radio needs to be sufficiently sensitive to receive very weak signals, but it must also be able to manage the strong signals without overloading.

As the range of signals that any receiver needs to handle may extend over 100dB or more, the strong signal performance is important. Overloading can lead to effects that can mask the wanted signal and actually reduce the sensitivity.

There are several key aspects and parameters that detail the radio performance in the presence of strong signals, each of which is key to the performance in a particular area.

With the proliferation of cell phones, Bluetooth devices, Wi-Fi, NFC, as well as more traditional radio systems, it is necessary for all of these to work in the presence of the others which may be in close proximity and radiating signals on adjacent channels or nearby frequencies. Accordingly the receiver overload and strong signal handling capability is very important.

Key overload and strong signal performance parameters

The overall radio overload and strong signal handling performance is governed by a number of separate specifications and parameters:

•***Receiver blocking:*** Radio receiver blocking occurs when a strong signal close to that being received reduces the sensitivity of the receiver. It is very important, especially in these days where there are many short range, and other longer range wireless cellular and other radio communications devices around.

•***Intermodulation performance :*** Intermodulation distortion and intermodulation performance are important parameters for a receiver performance. The presence of intermodulation products gives rise to unwanted signals being generated which may mask the wanted signal. These intermodulation present themselves as signal and may appear as 'real' signals, sometimes making a band that may have little activity, and much busier and full of signals.

•***Intercept point:*** The Intercept Point, or possibly more correctly, the third order intercept point gives an indication of the strong signal handling capacity of an amplifier, mixer or receiver. It is the level on a graph where the level of the third order products equal the wanted products, i.e. where the lines for the levels intercept.

•***Cross modulation :*** As the name implies, cross modulation manifests itself by transferring the modulation on one very strong signal onto other signals being received.

RF amplifier & receiver overload

One of the key elements of any receiver that governs its overload or strong signal handling capability is the RF amplifier. Its performance is key to the performance of the whole receiver.

Under normal conditions the RF amplifier of a radio receiver should remain linear with the output remaining proportional to the input. However, even the best RF amplifiers have limits to their output capability. Beyond a certain point the output can no lnger rise in proportion to the input as the amplifier enters a region where compression starts. When this happens their output starts to limit and the output is less than expected.

Compression in itself is not a problem for receiver overload performance. The absolute values of a signal are of little value and in any case the automatic gain control, AGC, used in many radio receivers means that the gain is reduced when strong signals are being received.

It is the side effects of compression give rise to major problems. Effects like intermodulation distortion, cross modulation, blocking and others mean that the operation of the radio receiver can be seriously impaired. It is these aspects which are of great importance for the overload performance of in the radio receiver design.

In view of the importance of the various aspects of overloading, a number of specifications quantify the various problems caused. However to look at these it is necessary to look at the basic effects and how they arise.

RF mixer & receiver overload

Another element of the receiver that has a major bearing on the strong signal handling performance is the first mixer. The performance of the mixer has a major effect on the receiver overload and strong signal handling performance.

To obtain the best radio overload performance a high level mixer is used. A high level mixer has a high level local oscillator input level. This enables it to cope with the high level signals that may give rise to problems with overload.

Improving receiver overload performance

To improve the radio overload and strong signal handling performance prevent these problems occurring at reasonable signal levels, radio receivers have a number of methods of reducing the signals levels:

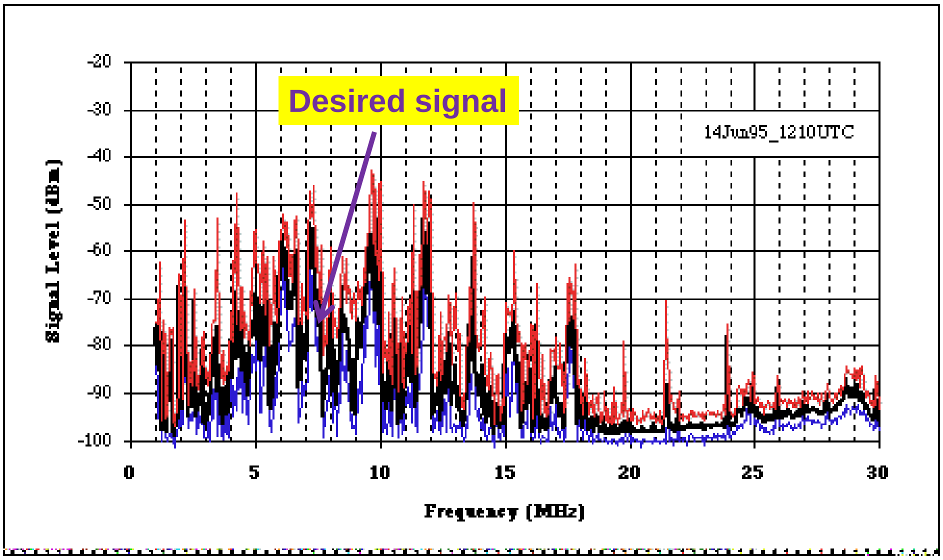
•***High level RF amplifier :*** To ensure the optimum radio overload performance, the first RF amplifier should be able to cater for high level signals while still remaining linear. It should have a high third order intercept point.

•***High level mixer:*** Likewise to ensure the mixer does not become overloaded by any strong signals that may be encountered, it should have as high a third order intercept as possible commensurate with other factors. For the best performance it should have a high level local oscillator input level.

•***AGC automatic gain control:*** Many receivers have a scheme known as an automatic gain control built in. This takes a sample of the output signal level and reduces the gain of the early stages. This works well for most situations, but it may not be able to prevent the earliest stages of the radio receiver from overloading. This is particularly true when signals are off the received channel, because these signals will not affect the AGC, but will still be presented to first stages of the receiver before they are filtered out.

•***Input RF attenuator:*** Some specialist radio receivers may incorporate an RF attenuator. This can be used to reduce the RF input level when strong signals are present.

Any radio receiver design will need to balance the requirements for strong signal handling and radio overload performance with those for other aspects of the design like sensitivity and other parameters. Achieving excellent strong signal handling and overload performance will be a balance of many factors including cost.



Al Penney
VO1NO

Fundamental Overload

- AKA **Front End Overload** or **Receiver Overload**.
- Unwanted signal is received on **all** or most frequencies.
- Signals enter the device through **antenna** or **any wires** connected to it.
- CW may cause “**pumping**” of RX audio.
- SSB may cause **distorted** RX audio.
- Moving antenna further away may help.

Al Penney
VO1NO

Fundamental Overload

Most cases of interference are caused by fundamental overload. The world is filled with RF signals. Properly designed equipment should be able to select the desired signal, while rejecting all others.

Unfortunately, because of design deficiencies such as inadequate shields or filters, some equipment is unable to reject strong out-of-band signals.

A strong fundamental signal can enter equipment in several different ways. Most commonly, it is conducted into the equipment by wires connected to it. Possible conductors include antennas and feed

lines, interconnecting cables, power lines and ground wires. TV antennas and feed lines, telephone or speaker wiring and ac power leads are the most common points of entry.

The effect of an interfering signal is directly related to its strength. The strength of a radiated signal diminishes with the square of the distance from the source. When the distance from the source

doubles, the strength of the electromagnetic field decreases to one-fourth of its strength at the original distance from the source. This characteristic can often be used to help solve EMI cases. You can

often make a significant improvement by moving the victim equipment and the antenna farther away from each other.

Cross Modulation

- **Cross Modulation** is the term given when a strong signal enters a radio and is rectified at some stage, modulating the intended signal.
- Primarily an **Amplitude Modulation** phenomena.
- Most common on AM radios, but was observed on older (NTSC) television sets.

Al Penney
VO1NO

Cross Modulation in Radio Receivers

Cross modulation is an effect noticed in radio receivers when the amplitude modulated elements of a strong signal appear on other received signals.

Cross modulation is a parameter used for radio receivers where strong signals with an amplitude modulated component are used. Amplitude and quadrature amplitude modulation are two examples.

It is found that the strong signal may cause sections of the receiver to become non-linear and in this way the varying amplitude transfers over to other signals.

Effectively, cross modulation is the transfer of modulation from one signal, typically a much stronger one, to another signal, typically a weaker one, due to non-linearities in the receiver chain.

Cross modulation basics

Cross modulation normally arises out of imperfect mixer performance in the radio, although it can easily occur in one of the RF amplifiers. As it is a third order effect, a receiver with a good third order intercept point should also exhibit good cross modulation performance.

To specify the cross modulation performance the effect of a strong AM carrier on a smaller wanted signal is noted. Generally the level of a strong carrier with 30% modulation needed to produce an output 20 dB below that produced by the wanted signal. The wanted signal level also has to be specified and 1mV or -47dBm (i.e. a signal 47 dB below 1 mW) is often taken as standard, together with an offset frequency of 20 kHz.

Cross modulation specifications

In instances where cross modulation is an issue it needs to be specified. To ensure that it is possible to compare the performance of different radios and also to enable benchmarks to be set, it is necessary to have a standard method of specifying it.

Cross modulation is the amount of amplitude modulation which is transferred from an off-channel and unwanted signal to the required one being received.

Cross modulation affects

Cross modulation is really only applicable to instances where amplitude modulation is used. In the early days of radio, it was noticed on amplitude modulated signals like broadcast transmissions, but today there are other signals that have amplitude modulation components.

•***AM broadcast receivers:*** This is traditionally the area where cross modulation effects had been noticed. When listing to weaker AM broadcast signals in the presence of very strong off channel signals, the modulation of the stronger signal or signals was transposed onto the weaker wanted signal. When broadcast receivers were located close to a broadcast transmitter, it could become an annoying problem.

•***Analogue television receivers:*** Although analogue television has now virtually been overtaken by digital television, it is still used occasionally and it was found that cross modulation occurred in some areas.

The most widely used form of modulation used with analogue television systems is vestigial sideband, VSB. It is effectively a form of AM where one of the sidebands has a reduced upper bandwidth. In televisions sets cross modulation manifests itself by creating a ghost image under the wanted on-channel station being received. It can be annoying if television stations are not all geographically co-located, and a more distant signal is being received in presence of a much more local and stronger off-channel signal.

While radio receiver cross modulation may not have the visibility in terms of receiver specifications that it previously had, it is still very important, especially in scenarios in which the modulations schemes used have an amplitude component.

Intermodulation

- **"Intermod"** is sometimes incorrectly called Cross Modulation, but is a different phenomena.
- It is the result of **two or more signals** of different frequencies **being mixed together**, forming **additional signals at frequencies** that are **not, in general, at harmonic frequencies** (integer multiples) of either.
- The **mixing** usually takes place **inside the receiver,** but can even take place at rusty fence joints (Passive Intermodulation – PIM)!
- **Very prevalent problem** on **2M and 70cm** FM when driving through **downtown!**

Al Penney
VO1NO

Intermodulation (**IM**) or **intermodulation distortion** (**IMD**) is the amplitude modulation of signals containing two or more different frequencies, caused by nonlinearities or time variance in a system. The intermodulation between frequency components will form additional components at frequencies that are not just at harmonic frequencies (integer multiples) of either, like harmonic distortion, but also at the sum and difference frequencies of the original frequencies and at sums and differences of multiples of those frequencies.

Intermodulation is caused by non-linear behaviour of the signal processing (physical equipment or even algorithms) being used.

As explained in a previous section, intermodulation can only occur in non-linear systems. Non-linear systems are generally composed of *active* components, meaning that the components must be biased with an external power source which is not the input signal (i.e. the active components must be "turned on").

Passive intermodulation (PIM), however, occurs in passive devices (which may include cables, antennas etc.) that are subjected to two or more high power tones. The PIM product is the result of the two (or more) high power tones mixing at device nonlinearities such as junctions of dissimilar metals or metal-oxide junctions, such as loose corroded connectors. The higher the signal amplitudes, the more pronounced the effect of the nonlinearities, and the more prominent the intermodulation that occurs — even though upon initial inspection, the system would appear to be linear and unable to generate intermodulation.

It is also possible for a single broadband carrier to generate PIM if it passes through a PIM generating surface or defect. These distortions would show up as side lobes in a telecommunication signal and interfere with adjacent channels and impede reception.

PIM can be severe problem in modern communication systems. Paths that share both high power transmission and the receive signal are most susceptible to this kind of interference. Once PIM interference finds its way to receive path, it can not be filtered or separated.

Sources of PIM

Ferromagnetic materials are the most common materials to avoid and include ferrites, nickel, (including nickel plating) and steels (including some stainless steels). These materials exhibit hysteresis when exposed to reversing magnetic fields, resulting in PIM generation.

PIM can also be generated in components with manufacturing or workmanship defects, such as cold or cracked solder joints or poorly made mechanical contacts. If these defects are exposed to high RF currents, PIM can be generated. As a result, RF equipment manufacturers perform factory PIM tests on components, to eliminate PIM caused by these design and manufacturing defects.

PIM can also be inherent in the design of a high power RF component where RF current is forced to narrow channels or restricted.

In the field, PIM can be caused by components that were damaged in transit to the cell site, installation workmanship issues and by external PIM sources. Some of these include:

•Contaminated surfaces or contacts due to dirt, dust, moisture or oxidation.

•Loose mechanical junctions due to inadequate torque, poor alignment or poorly prepared contact surfaces.

•Loose mechanical junctions caused during transportation, shock or vibration.

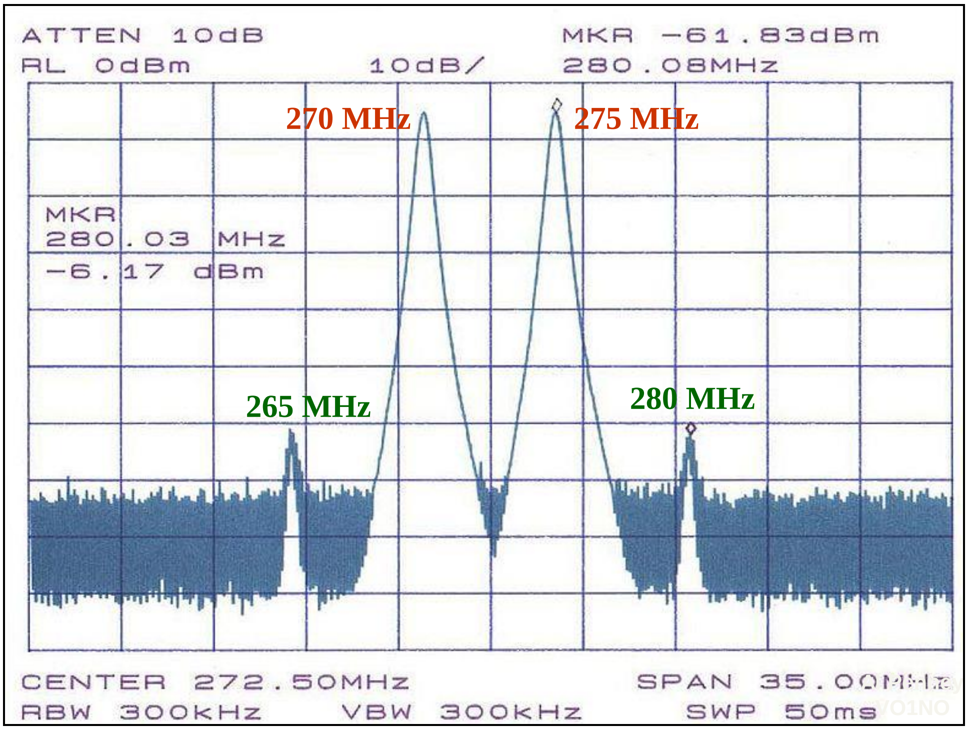
•Metal flakes or shavings inside RF connections.

•Inconsistent metal-to-metal contact between RF connector surfaces caused by any of the following:

•Trapped dielectric materials (adhesives, foam, etc.), cracks or distortions at the end of the outer conductor of coaxial cables, often caused by overtightening the back nut during installation, solid inner conductors distorted in the preparation process, hollow inner conductors excessively enlarged or made oval during the preparation process.

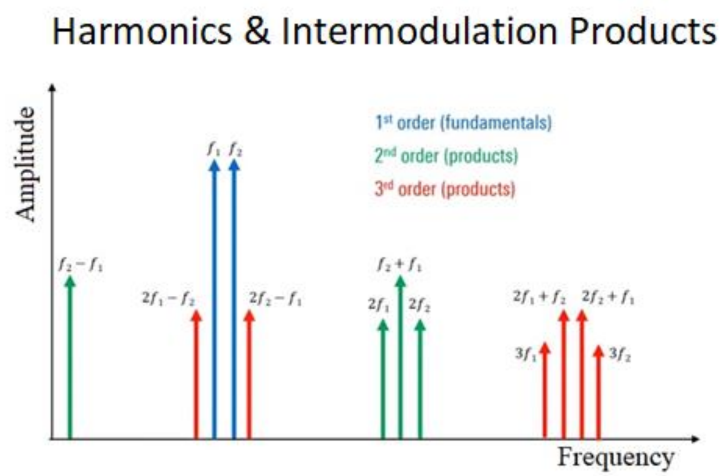
•PIM can also occur in connectors, or when conductors made of two galvanically unmatched metals come in contact with each other.

•Nearby metallic objects in the direct beam and side lobes of the transmit antenna including rusty bolts, roof flashing, vent pipes, guy wires, etc.



Frequency Spectrum of intermodulation distortion in a radio-frequency signal passed through the linear broad-band amplifier I built. The process of intermodulation is due to third-order harmonics of closely spaced signals. I tested this phenomenon with two signals: a Local Oscillator (LO) at 270 MHz, +0dBm, and an RF signal at 275 MHz. (Closer spacing would push the limitations of the RF spectrum analyzer resolution). Clear intermodulation products were seen at 265 and 280 MHz. As seen on the attached graph, the intermodulation power is 55.66 dB lower than the signal power. This graph nicely shows our desired signal peaks, as well as the side-band intermodulation. These closely spaced distortions would likely interfere with our signal, since it would be difficult to build a high-quality filter to cancel them out in our application. However, their overall power is more than 50 dB below the desired signal, which was sufficiently low for our purposes. We used this measurement to estimate the IP3 (third order intercept point) parameter.

Intermod can get Complicated!



Al Penney
VO1NO

Intermodulation Distortion (IMD) occurs when two or more signals are used in a non-linear system. The spectrum at the output of the non-linear device will not only consist of the original signals but will also contain the sum and difference of the input signals along with their harmonics. Hence, if a non-linear system has two signals at its input, say at frequencies f1 and f2 then the non-linearity will give rise to other output signals at various frequencies, i.e., f1 + f 2, f2 – f1, 2f1 and 2f2 which are also known as **2nd order intermodulation products**. The products 2f1 and 2f2 are known as "*Harmonics*" which are nothing but replicas of a signal appearing at integer multiples of the fundamental signal. These sideband frequencies are considered to be undesirable.

In the next step, these 2nd order intermodulation products will mix with the original signals that will give rise to **3rd order intermodulation products**. It should be noted that each individual signal, including original signals (f1 and f2) and 2nd order intermodulation products (f1 + f 2, f2 – f1, 2f1 and 2f2), will be added and subtracted with/from each other to give rise to more signals. Most of these intermodulation signals are not close to the original signal so can easily be filtered out or do not cause issues. However there are two intermodulation products i.e., 2f1-f2 and 2f2-f1 which can be troublesome and can cause interference as they are close to the original signal. These products are known to cause intermodulation distortion.

The typical way of dealing with these troublesome IMD products is through filtering, but this becomes difficult when the products are very close to the desired (fundamental) frequencies. These 3rd order intermodulation products are of great concern as they are difficult to filter out, unlike 2nd order distortion products, which appears to be at a greater distance w.r.t the original signals (f1 and f2). The additional frequency content created by the 3rd order distortion is often referred to as 'Spectral Regrowth'. In a transmitter, spectral regrowth resulting from poor linearity can interfere with other wireless channels. In a receiver, by contrast, it can cause out-of-band signals to distort the signal of interest. IMD and harmonics create leakage into adjacent channels, noise or distortion, which degrades the overall systems performance.

Some Interesting Things to Note:

•The amplitude of harmonics usually decreases as the harmonics order increases. Higher-order harmonics have very low amplitudes and thus can usually be ignored. And most of the higher-frequency products often fall outside of amplifier bandwidth, filter passbands, etc.

•Third-order intermodulation products have an amplitude proportional to the cube of the input signal whereas second-order components have an amplitude proportional to the square of the input signal.

•The best way to avoid IMD products is to operate the device in the linear region before it starts generating distortions.

•The order of harmonics and intermodulation is the sum of their (unsigned) coefficients:

•2f1 is second-order (2)

•f1 + f2 is also second order (1+1)

•3f1 is third order (3)

•2f2 – f1 and 2f2 + f1 are both third-order (2 + 1)

Spurious Emissions

- Transmitter is inadvertently transmitting signals **not on intended frequency**.
- Could be **harmonics** – multiples of the intended signal.
- Could be non-harmonic – signals generated by the **peculiarities** of the transmitter's design.
- These include **Mixing Products** and **Parasitics**.
- Such problems are usually rare with modern transmitters.

Al Penney
VO1NO

A **spurious emission** is any radio frequency not deliberately created or transmitted, especially in a device which normally does create other frequencies. A harmonic or other signal outside a transmitter's assigned channel would be considered a spurious emission.

From ITU, 1.145 Spurious emission: Emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products but exclude out-of-band emissions.

Spurious signals are unintended signals that can result from harmonics, intermodulation, frequency conversion, or EMI (electromagnetic interference).

Spurious Emissions

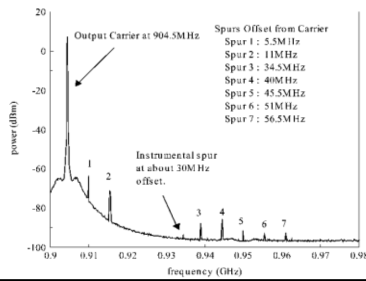
All transmitters generate some (hopefully few) RF signals that are outside their allocated frequency bands. These out-ofband signals are called spurious emissions, or *spurs*. Spurious emissions can be discrete signals or wideband noise. Harmonics, the most common spurious emissions, are signals at exact multiples of the operating (or *fundamental*) frequency.

Other discrete spurious signals are usually caused by the superheterodyne mixing process used in most modern transmitters. The diagram on the next page shows the spectral output of a transmitter, including harmonics and mixing products.

Transmitters may also produce broadband noise and/or "parasitic" oscillations. If these unwanted signals cause interference to another radio service, FCC regulations require the owner to correct the problem.

Mixing Products, DDS Noise etc.

- Super heterodyne **mixing** in transmitters can create spurious emissions.
- **Direct Digital Synthesis** and **Phase Locked Loop** systems used to generate RF signals can also create spurious emissions.



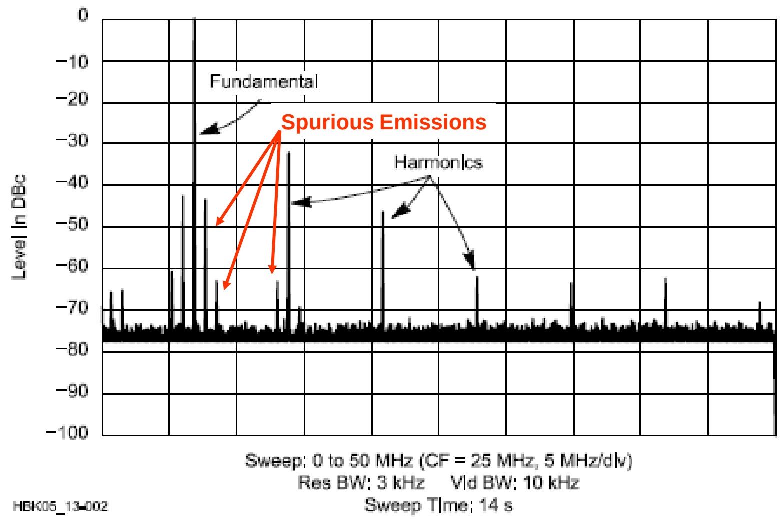
Al Penney
VO1NO

What is Direct Digital Synthesis?

Direct digital synthesis (DDS) is a method of producing an analog waveform—usually a sine wave—by generating a time-varying signal in digital form and then performing a digital-to-analog conversion. Because operations within a DDS device are primarily digital, it can offer fast switching between output frequencies, fine frequency resolution, and operation over a broad spectrum of frequencies. With advances in design and process technology, today’s DDS devices are very compact and draw little power.

Other discrete spurious signals are usually caused by the superheterodyne mixing process used in most modern transmitters

Harmonics & Spurious Emissions



Al Penney
VO1NO

Harmonics are undesired transmissions that are multiples of the intended transmission frequency. Almost all RF transmitters produce some harmonics at low power levels, as compared to the *fundamental frequency* that is the desired transmission frequency. The 2nd harmonic, double the frequency of the fundamental, and the 3rd harmonic, triple the frequency of the fundamental, are usually the strongest harmonics produced by a transmitter. Harmonics produced by an ill functioning amateur radio transmitter may lie well outside of the amateur frequency bands and cause interference to other radio services or electronic devices! Harmonics are another potential cause of radio frequency interference.

Parasitics

- **Undesirable oscillations** in transmitter.
- Caused by output coupled back to input of amplifier, providing **positive feedback** at some **unwanted frequency**.
- Can be **above or below** intended frequency.
- **Proper design** can prevent parasitics.

Al Penney
VO1NO

Parasitic oscillation is an undesirable electronic oscillation (cyclic variation in output voltage or current) in an electronic or digital device. It is often caused by feedback in an amplifying device. The problem occurs notably in RF, audio, and other electronic amplifiers as well as in digital signal processing. It is one of the fundamental issues addressed by control theory.

Parasitic oscillation is undesirable for several reasons. The oscillations may be coupled into other circuits or radiate as radio waves, causing electromagnetic interference (EMI) to other devices. The oscillations waste power and may cause undesirable heating. For example, an audio power amplifier that goes into parasitic oscillation may generate enough power to damage connected speakers. A circuit that is oscillating will not amplify linearly, so desired signals passing through the stage will be distorted.

Causes of parasitic oscillation

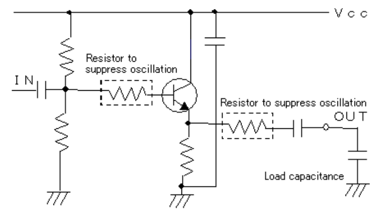
Parasitic oscillation in an amplifier stage occurs when part of the output energy is coupled into the input, with the correct phase and amplitude to provide positive feedback at some frequency. The coupling can occur directly between input and output wiring with stray capacitance or mutual inductance between input and output. In some solid-state or vacuum electron devices there is sufficient internal capacitance to provide a feedback path. Since the ground is common to both input and output, output current flowing through the impedance of the ground connection can also couple signals back to the input.

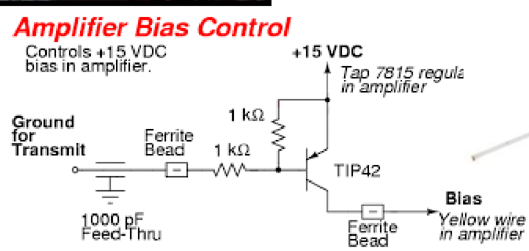
Similarly, impedance in the power supply can couple input to output and cause oscillation. When a common power supply is used for several stages of amplification, the supply voltage may vary with the changing current in the output stage. The power supply voltage changes will appear in the input stage as positive feedback. An example is a transistor radio which plays well with a fresh battery, but squeals or "motorboats" when the battery is old.

Mitigation

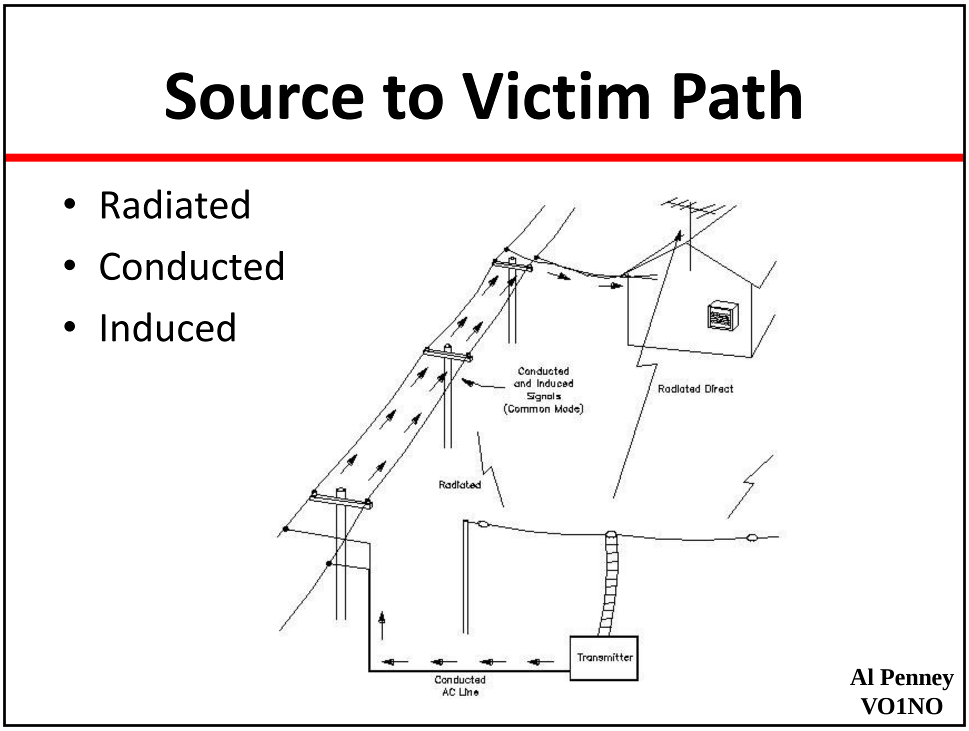
Several measures are used to prevent parasitic oscillation. Amplifier circuits are laid out so that input and output wiring are not adjacent, preventing capacitive or inductive coupling. A metal shield may be placed over sensitive portions of the circuit. Bypass capacitors may be put at power supply connections, to provide a low-impedance path for AC signals and prevent interstage coupling through the power supply. Where printed circuit boards are used, high- and low-power stages are separated and ground return traces are arranged so that heavy currents don't flow in mutually shared portions of the ground trace. In some cases the problem may only be solved by introduction of another feedback *neutralization* network, calculated and adjusted to eliminate the negative feedback within the passband of the amplifying device.

Parasitic Suppression





Al Penney
VO1NO



SOURCE-PATH-VICTIM

All cases of EMI involve a *source* of electromagnetic energy, a device that responds to this electromagnetic energy (*victim*) and a transmission path that allows energy to flow from the source to

the victim. Sources include radio transmitters, receiver local oscillators, computing devices, electrical noise, lightning and other natural sources.

There are **three ways that EMI can travel from the source to the victim: radiation, conduction and induction**.

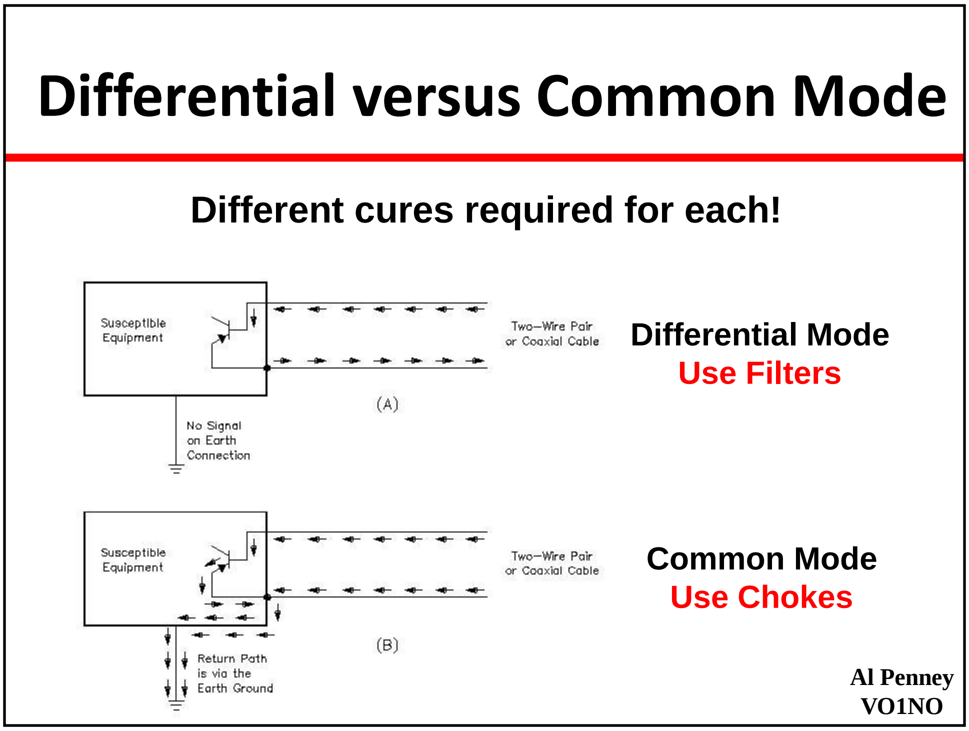
Radiated EMI propagates by electromagnetic radiation from the source, through space to the victim.

A **conducted signal** travels over wires connected to the source and the victim.

Induction occurs when two circuits are magnetically (and in some cases, electrically) coupled.

Most EMI occurs via conduction, or some combination of radiation and conduction. For example, a signal is radiated by the source and picked up by a conductor attached to the victim (or directly

by the victim's circuitry) and is then conducted into the victim. EMI from induction is rare.



DIFFERENTIAL VS COMMON-MODE

It is important to understand the differences between differential-mode and common-mode conducted signals (see **slide**). Each of these conduction modes requires different EMI cures. Differential mode cures, (the typical high-pass filter, for example) do not attenuate common mode signals. On the other hand, a typical common-mode choke does not affect interference resulting from a differential mode signal.

Differential-mode currents usually have two easily identified conductors. In a two-wire transmission line, for example, the signal leaves the generator on one line and returns on the other. When the two conductors are in close proximity, they form a transmission line and there is a 180° phase difference between their respective signals. It's relatively simple to build a filter that passes desired signals and shunts unwanted signals to the return line. Most *desired* signals, such as the TV signal inside a coaxial cable are differential mode signals.

In a common-mode circuit, many wires of a multiwire system act as if they were a single wire. The result can be a good antenna, either as a radiator or as a receptor of unwanted energy. The return path is usually earth ground. Since the source and return conductors are usually well separated, there is no reliable phase difference between the conductors and no convenient place to shunt unwanted signals.

Toroid chokes are the answer to common-mode interference. (The following explanation applies to rod cores as well as toroids, but since rod cores may couple into nearby circuits, use them only as a last resort.) Toroids work differently, but equally well, with coaxial cable and paired conductors. A common-mode signal on a coaxial cable is usually a signal that is present on the *outside* of the cable *shield*. When we wrap the cable around a ferrite-toroid core, the choke appears as a reactance in series with the outside of the shield, but it has no effect on signals inside the cable because their field is (ideally) confined inside the shield.

With paired conductors such as zip-cord, signals with opposite phase set up magnetic fluxes of opposite phase in the core. These "differential" fluxes cancel each other, and there is no net reactance for the differential signal. To common-mode signals, however, the choke appears as a reactance in series with the line. Toroid chokes work less well with single-conductor leads. Because there is no return current to set up a canceling flux, the choke appears as a reactance in series with *both* the desired and undesired signals.

What to do….

Al Penney
VO1NO

What to do….

When you receive a complaint!

Al Penney
VO1NO

TROUBLESHOOTING EMI

Most EMI cases are complex. They involve a source, a path and a victim. Each of these main components has a number of variables: Is the problem caused by harmonics, fundamental overload, conducted emissions, radiated emissions or a combination of all of these factors? Should it be fixed with a low-pass filter, high-pass filter, common- mode chokes or ac-line filter? How about shielding, isolation transformers, a different ground or antenna configuration?

By the time you finish with these questions, the possibilities could number in the millions. You probably will not see your exact problem and cure listed in this book or any other. You must diagnose the problem!

Troubleshooting an EMI problem is a three-step process, and all three steps are equally important:

• Identify the problem

• Diagnose the problem

• Cure the problem.

What to do….

- First.. **REMAIN CALM!**
- Express empathy and concern.
- Do not criticize their equipment.
- Try to explain the issue, and indicate that there are ways to correct the problem.
- Build a **climate of cooperation**.
- Do not automatically assume blame however.

Al Penney
VO1NO

Sooner or later, nearly every Amateur Radio operator will have a problem with interference. Most cases of interference can be cured! The proper use of "diplomacy" skills and standard cures will usually solve the problem.

Pieces of the Problem

Every interference problem has two components — the equipment that is involved and the people who use it. A solution requires that we deal with both the equipment and the people effectively.

Responsibility

When an interference problem occurs, we may ask "Who is to blame?" The ham and the neighbor often have different opinions. It is almost natural (but unproductive) to fix blame instead of the problem.

No amount of wishful thinking (or demands for the "other guy" to solve the problem) will result in a cure for interference. Each individual has a unique perspective on the situation, and a different degree of understanding of the personal and technical issues involved. On the other hand, each person has certain responsibilities to the other and should be prepared to address those responsibilities fairly.

Personal Diplomacy

What happens when you first talk to your neighbor sets the tone for all that follows. Any technical solutions cannot help if you are not allowed in your neighbor's house to explain them! If the interference is not caused by spurious emissions from your station, however, you should be a locator of solutions, not a provider of solutions.

Your neighbor will probably *not* understand all of the technical issues — at least not at first. Understand that, regardless of fault, an interference problem is annoying to your neighbor. Let your neighbor know that you want to help find a solution and that you want to begin by talking things over.

Talk about some of the more important technical issues, in non-technical terms. Interference can be caused by unwanted signals from your transmitter. Assure your neighbor that you will check your station thoroughly and correct any problems. You should also discuss the possible susceptibility of consumer equipment. You may want to print a copy of the RFI information found on *ARRLWeb* at: **www.arrl.org/news/rfi/neighbors.html**.

Your neighbor will probably feel much better if you explain that you will help *find* a solution, even if the interference is *not* your fault. This offer can change your image from neighborhood villain to hero, especially if the interference is not caused by your station. (This is often the case.)

What to do….

- Determine if it is actually you causing the interference (is it really EMI?):
  - It may be a fault with the consumer equipment unrelated to your transmissions;
  - Ensure the TV/radio can receive a good signal;
  - Compare dates and times against your logbook;
  - May only be specific bands, modes, power levels or antennas that cause interference;
  - Try to conduct tests if the neighbour agrees.

Al Penney
VO1NO

Identify the Problem

Is It Really EMI? — Before trying to solve a suspected case of EMI, verify that the symptoms actually result from external causes. A variety of equipment malfunctions or external noise can look like

interference. "Your" EMI problem might be caused by another ham or a radio transmitter of another radio service, such as a local CB or police transmitter.

Is It Your Station? — If it appears that your station is involved, operate your station on each band, mode and power level that you use. Note all conditions that produce interference. If no transmissions produce the problem, your station *may* not be the cause. (Although some contributing factor may have been missing in the test.)

Have your neighbor keep notes of when and how the interference appears: what time of day, what station, what other appliances were in use, what was the weather? You should do the same whenever

you operate. If you can readily reproduce the problem with your station, you can start to troubleshoot the problem.

What to do….

- **Under NO circumstances should you make internal modifications to someone else's equipment!**
- You may void any warranty, and you will forever be responsible for repairing it!
- Only licensed technicians should do such work.
- Emphasize that you are ready to assist a qualified technician.

Al Penney
VO1NO

Diagnose the Problem

Look Around — Aside from the brain, eyes are a troubleshooter's best tool. Look around. Installation defects contribute to many EMI problems. Look for loose connections,

shield breaks in a cable-TV installation or corroded contacts in a telephone installation. Fix these first.

Problems that occur only on harmonics of the fundamental signal usually indicate the transmitter. Harmonics can also be generated in nearby semiconductors, such as an unpowered VHF receiver left connected to an antenna, or a corroded connection in a tower guy wire. Harmonics can also be generated in the front-end components of the TV or radio experiencing interference.

Is the wiring connected to the victim equipment resonant on one or more amateur bands? If so, a common-mode choke placed at the middle of the wiring may be an easy cure.

These are only a few of the questions you might need to ask. Any information you gain about the systems involved will help find the EMI cause and cure.

Solving RFI Problems

- First – **clean up your own station**!
  - Ensure all connections tight.
  - Ensure equipment is properly grounded.
  - Install Low-Pass or Band-Pass filters.
  - Have you made any recent changes that might cause problems?
  - Have a qualified technician confirm transmitter meets specifications for spurious signal attenuation.
  - Remember – setting **mic gain too high** or **over-driving an amplifier** can cause **splatter!**

Al Penney
VO1NO

Prepare Your Home

The first step toward curing an interference problem is to make sure your own signal is clean. You must eliminate all interference in your own house to be sure you are not causing the interference! This

is also a valuable troubleshooting tool: If you know your station is clean, you have cut the size of the problem in half! If the FCC ever gets involved, you can demonstrate that you are not interfering with your

own equipment.

Apply EMI cures to your own consumer electronics equipment. When your neighbor sees your equipment working well, it demonstrates that filters work and cause no harm.

To clean up your station, clean up the mess! A rat's nest of wires, unsoldered connections and so on in your station can contribute to EMI. To help build a better relationship, you may want to show your

station to your neighbor. A clean station looks professional; it inspires confidence in your ability to solve the EMI problem.

Install a transmit filter (low-pass or band-pass) and a reasonable station ground. (If the FCC becomes involved, they will ask you about both items.) Show your neighbor that you have installed the

necessary filter on your transmitter and explain that if there is still interference, it is necessary to try filters on the neighbor's equipment, too.

Operating practices and station-design considerations can affect EMI. Don't overdrive a transmitter or amplifier; that can increase its harmonic output. You can take steps to reduce the strength of your

signal at the victim equipment. This might include reducing transmit power. Locate the antenna as far as possible from susceptible equipment or its wiring (ac line, telephone, cable TV). Antenna orientation may be important. For example, if your HF dipole at 30 ft is coupling into the neighbor's overhead cable-TV drop, that coupling could be reduced 20 dB by changing to a vertical antenna — even

more by orienting the antenna so that the drop is off its end. Try different modes; CW or FM usually do not generate nearly as much telephone interference as AM or SSB, for example.

At Your Station — Make sure that your own station and consumer equipment are clean. This cuts the size of the problem in half! Once this is done, you won't need to

diagnose or troubleshoot your station later. Also, any cures successful at your house may work at your neighbor's as well. If you do have problems in your own

house, refer first to the Transmitter section of this chapter, or continue through the troubleshooting steps and specific cures and take care of your own problem first.

Low Pass Filter – Used on Radio

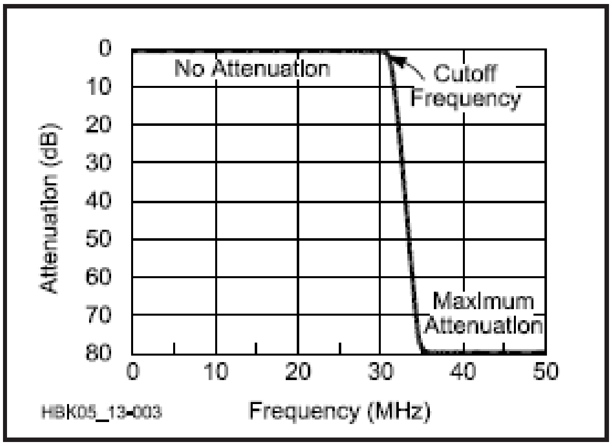


Fig 13.3 — An example of a low-pass filter-response curve.

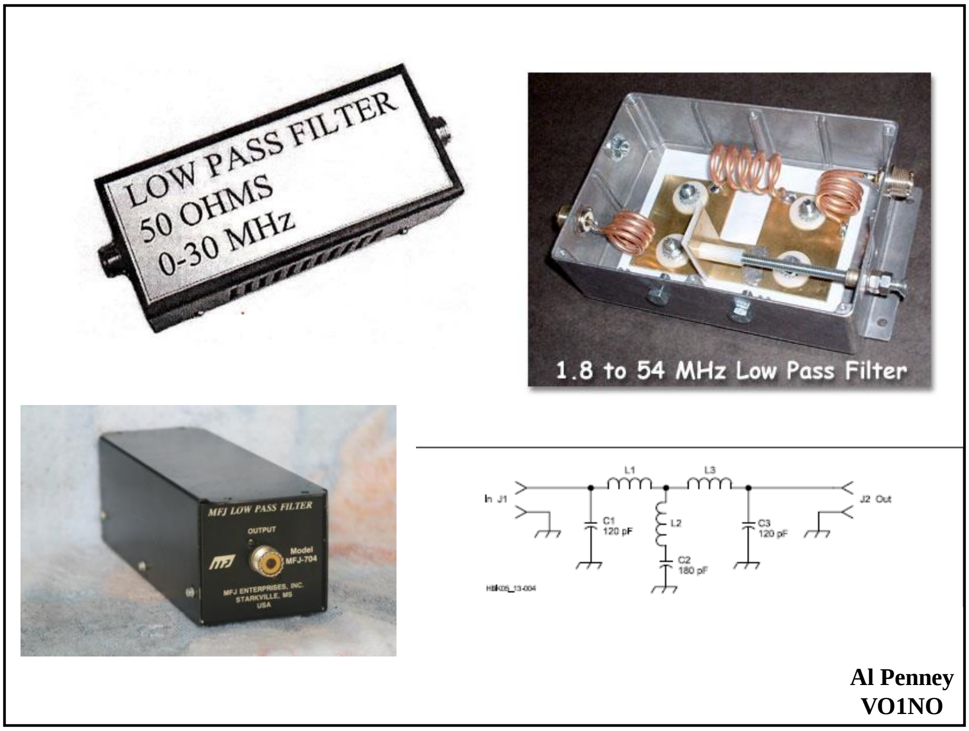
Al Penney
VO1NO

Low-pass filters pass frequencies below some cutoff frequency, while attenuating frequencies above that cutoff frequency. A typical low-pass filter curve is shown above. A schematic is shown nrxt slide. These filters are difficult to construct properly so you should buy one.

Filters

A major means of separating signals relies on their frequency differences. Filters offer little opposition to certain frequencies while blocking others. Filters

vary in attenuation characteristics, frequency characteristics and power-handling capabilities. The names given to various filters are based on their uses.



The filters must be of the same impedance as the overall system (radio, coax cable, antenna), usually 50 ohms for Amateur Radio.

Station Grounds

- An effective ground is an important part of an Amateur station.
- Usually 3 grounds:
  - AC safety ground;
  - Ground at antenna for lightning protection; and
  - Equipment ground in station for EMI control.
- Interaction can sometime contribute to RFI/EMI issues.

Grounds

An electrical ground is not a huge sink that somehow swallows noise and unwanted signals. Ground is a *circuit* concept, whether the circuit is small, like a radio receiver, or large, like the propagation

path between a transmitter and cable- TV installation. Ground forms a universal reference point between circuits.

This chapter deals with the EMC aspects of grounding. While grounding is not a cure-all for EMI problems, ground is an important safety component of any electronics

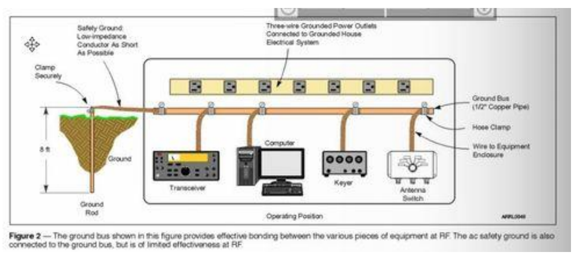
installation. It is part of the lightning protection system in your station and a critical safety component of your house wiring. Any changes made to a grounding system must not compromise these important safety considerations. Refer to the **Safety** chapter for important information about grounding.

Many amateur stations have several grounds: a safety ground that is part of the ac-wiring system, another at the antenna for lightning protection and perhaps another

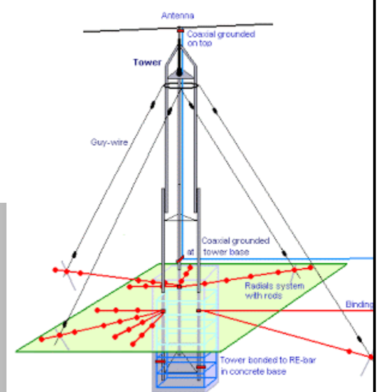
at the station for EMI control. These grounds can interact with each other in ways that are difficult to predict.

Grounding

AC Safety Ground



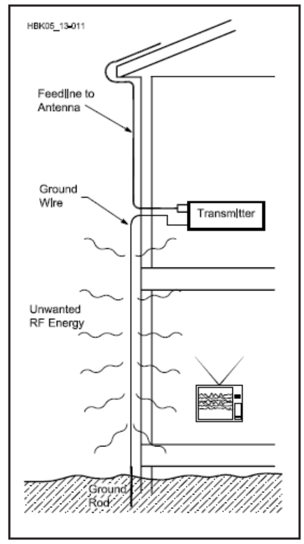
Station Equipment Ground



Antenna Lightning Ground

When a Ground isn't a Ground!

- A proper ground can eliminate some RFI/EMI problems.
- It can sometimes cause problems however, especially on VHF/UHF, and if ground lead is long.
- Ground lead can radiate in these circumstances.



Al Penney VO1NO

When is Ground not a Ground?

In many stations, it is impossible to get a good RF connection to earth ground. Most practical installations require several feet of wire between the station ground connection and an outside ground

rod. Many troublesome harmonics are in the VHF range. At VHF, a ground wire length can be several wavelengths long — a very effective long-wire antenna! Any VHF signals that are put on a long ground

wire will be radiated. This is usually not the intended result of grounding.

Take a look at the station shown above. In this case, the ground wire could very easily contribute to an interference problem in the downstairs TV set. While a station ground may cure some

transmitter EMI problems — either by putting the transmitter chassis at a low impedance reference point or by rearranging the problem so the "hot spots" are farther away from susceptible equipment

— it is not the cure-all that some literature has suggested. A ground is easy to install, and it may reduce stray fundamental or harmonic currents on your antenna lead; it is worth a try.

Solving RFI Problems

- Is interference similar on all bands?
  – If so, then it may be front end overload.
- Is your audio being received in addition to neighbour's favorite AM station?
  – If so, then it is Cross Modulation.
  – Your signal is being rectified in the receiver.

Al Penney
VO1NO

TROUBLESHOOTING EMI

Most EMI cases are complex. They involve a source, a path and a victim. Each of these main components has a number of variables: Is the problem caused by harmonics, fundamental overload, conducted emissions, radiated emissions or a combination of all of these factors? Should it be fixed with a low-pass filter, high-pass filter, common- mode chokes or ac-line filter? How about shielding, isolation transformers, a different ground or antenna configuration?

By the time you finish with these questions, the possibilities could number in the millions. You probably will not see your exact problem and cure listed in this book or any other. You must diagnose the problem!

Troubleshooting an EMI problem is a three-step process, and all three steps are equally important:

- Identify the problem
- Diagnose the problem
- Cure the problem.

Identify the Problem

Is It Really EMI? — Before trying to solve a suspected case of EMI, verify that the symptoms actually result from external causes. A variety of equipment malfunctions or external noise can look like

interference. "Your" EMI problem might be caused by another ham or a radio transmitter of another radio service, such as a local CB or police transmitter.

Is It Your Station? — If it appears that your station is involved, operate your station on each band, mode and power level that you use. Note all conditions that produce interference. If no transmissions produce the problem, your station *may* not be the cause. (Although some contributing factor may have been missing in the test.)

Have your neighbor keep notes of when and how the interference appears: what time of day, what station, what other appliances were in use, what was the weather? You should do the same whenever

you operate. If you can readily reproduce the problem with your station, you can start to troubleshoot the problem.

Diagnose the Problem

Look Around — Aside from the brain, eyes are a troubleshooter's best tool. Look around. Installation defects contribute to many EMI problems. Look for loose connections,

shield breaks in a cable-TV installation or corroded contacts in a telephone installation. Fix these first.

Problems that occur only on harmonics of the fundamental signal usually indicate the transmitter. Harmonics can also be generated in nearby semiconductors, such as an unpowered VHF receiver left connected to an antenna, or a corroded connection in a tower guy wire. Harmonics can also be generated in the front-end components of the TV or radio experiencing interference.

Is the wiring connected to the victim equipment resonant on one or more amateur bands? If so, a common-mode choke placed at the middle of the wiring may be an easy cure.

These are only a few of the questions you might need to ask. Any information you gain about the systems involved will help find the EMI cause and cure.

Steps to Take

- Insure covers are secure and connected to chassis.
- Check power cord. Three prong? If not polarized, reverse the plug.
- Are cords or speaker leads multiples of ¼ wavelength of frequencies used?
- Are connectors proper? Is coax spliced?
- Disconnect pieces of equipment to track down where interference is entering system.

Al Penney
VO1NO

OVERVIEW OF TECHNIQUES

Shields

Shields are used to set boundaries for radiated energy. Thin conductive films, copper braid and sheet metal are the most common shield materials. Maximum shield effectiveness usually requires solid sheet metal that completely encloses the source or susceptible circuitry or equipment. Small discontinuities, such as holes or seams, decrease shield effectiveness. In addition, mating surfaces between different parts of a shield must be conductive.

To ensure conductivity, file or sand off paint or other nonconductive coatings on mating surfaces.

TVI - Steps to Take

- For TV and cable systems, check for homemade splits instead of proper splitters.
- Also look for mixing 75 and 300 Ohm cable without proper baluns.
- Check for leakage by the cable system on 145.25 MHz. If signals are escaping, they can get in!

Al Penney
VO1NO

SPECIFIC CURES

Now that you have learned some EMI fundamentals, you can work on technical solutions. A systematic approach will identify the problem and suggest a cure.

Armed with your EMI knowledge, a kit of filters and tools, your local TC and a determination to solve the problem, it is time to diagnose the problem.

Most EMI problems can be solved by the application of standard cures. If you try these cures and they work, you may not need to troubleshoot the problem at

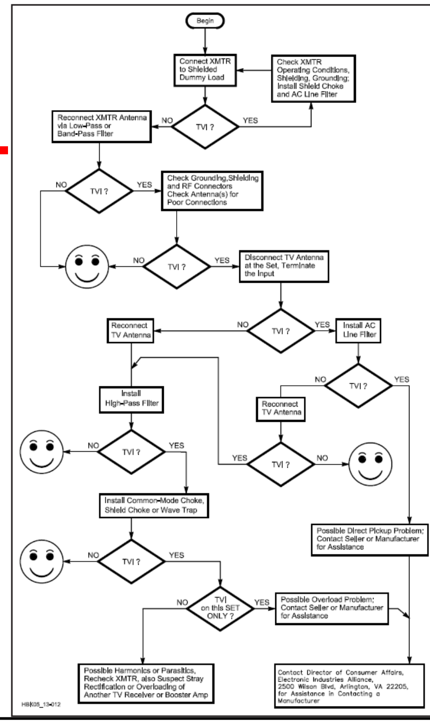
all. Perhaps if you can install a low-pass filter on your transmitter or a common mode choke on a TV, the problem will be solved.

You should also get a copy of *The ARRL RFI Book*. It's comprehensive and picks up where this chapter leaves off.

TVI

- Is EMI from harmonics, spurious emissions, or front end overload?
- Interference can get in via many paths.
- Antenna feedline and power line serve as excellent antennas!

Al Penney
VO1NO



Television Interference (TVI)

For a TV signal to look good, it must have about a 45 to 50 dB signal-to-noise ratio. This requires a good signal at the TV antenna-input connector. This brings up an important point: to have a good signal, you must be in a good signal area. The FCC does not protect fringe-area reception. TVI, or interference to any radio service, can be caused by one of several things:

• Spurious signals within the TV channel coming from your transmitter or station.

• The TV set may be overloaded by your transmitter's fundamental signal.

• Signals within the TV channel from some source other than your station, such as electrical noise, an overloaded mast-mounted TV preamplifier or a transmitter in another service.

• The TV set might be defective or misadjusted, making it look like there is an interference problem.

All of these potential problems are made more severe because the TV set is hooked up to *two* antenna systems: (1) the incoming antenna and its feed line and (2) the ac power lines. These two "long-wire" antennas can couple *a lot* of fundamental or harmonic energy into the TV set!

The TVI Troubleshooting Flowchart above is a good starting point.

High Pass Filter – Used on TV

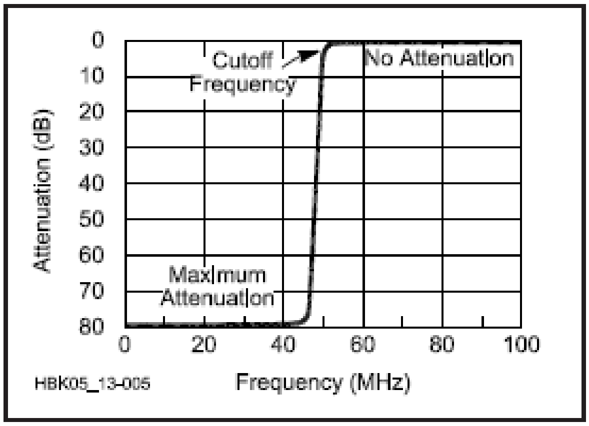
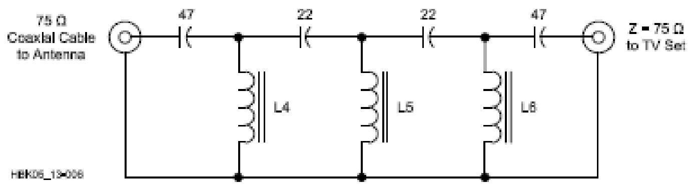


Fig 13.5 — An example of a high-pass filter response curve.

Al Penney
VO1NO

High-pass filters pass frequencies above some cutoff frequency while attenuating frequencies below that cutoff frequency. A typical high-pass filter curve is shown above. **The next slide** shows a schematic of a typical high-pass filter. Again, it is best to buy one of the commercially available filters.

High Pass Filter – Used on TV



Al Penney
VO1NO

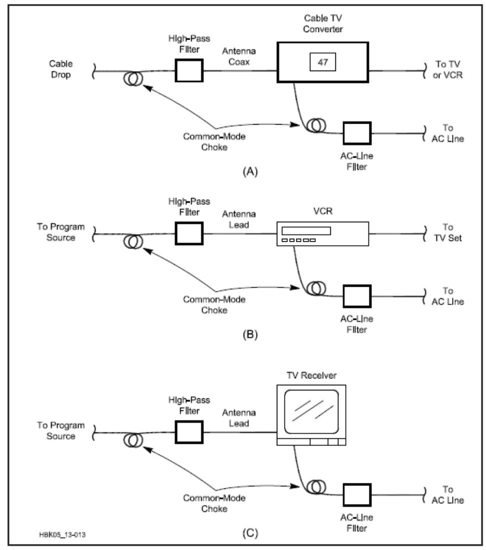
Other Filters

- **Bandpass** – Will pass frequencies within the specified range, but reject those above and below that range.
- **Band Stop** or **Band Reject** – Will pass all frequencies above and below the specified range, but reject those in that range.
- **Notch** – rejects the design frequency, allows all others to pass.

Al Penney
VO1NO

Common Mode Chokes

- Differential mode filters not effective against common mode signals.
- Must use **common mode chokes** instead.
- Usually ferrite.
- Wide variety of applications.
- If still interference after these measures, TV circuit is picking up signals directly.



Al Penney
VO1NO

Common-Mode Chokes

Common-mode chokes may be the best kept secret in Amateur Radio. The differential- mode filters described earlier are *not* effective against common-mode signals. To eliminate common-mode signals properly, you need common-mode chokes. They may help nearly any interference problem, from cable TV to telephones to audio interference caused by RF picked up on speaker leads.

Common-mode chokes usually have ferrite core materials. These materials are well suited to attenuate common-mode currents. Several kinds of common-mode chokes are shown in **Fig 13.8**.

The optimum size and ferrite material are determined by the application and frequency. For example, an ac cord with a plug attached cannot be easily wrapped on a small ferrite core. The characteristics of ferrite materials also vary with frequency.

Fundamental Overload

A television set can be overloaded by a strong, local RF signal. This happens because the manufacturer did not install the necessary filters and shields to protect the TV set from other signals present on the air. These design deficiencies can sometimes be corrected externally.

Start by determining if the interference is affecting the video, the sound or both. If it is present only on the sound, it is probably a case of audio rectification. (See the

Stereos section of this chapter.) If it is present on the video, or both, it could be getting into the video circuitry or affecting either the tuner or IF circuitry.

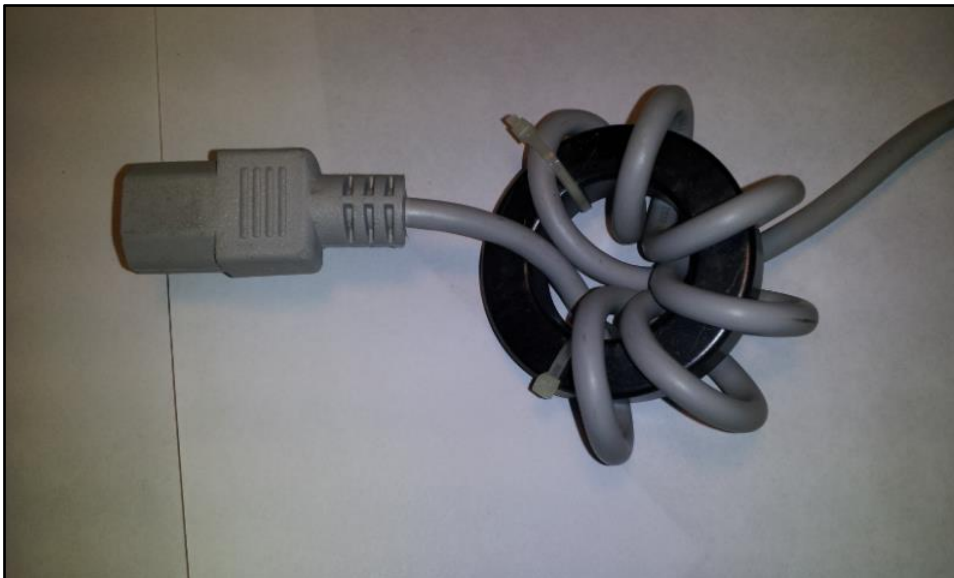
The first line of defense for an antenna connected TV is a high-pass filter. Install a high-pass filter directly on the back of the TV set. You may also have a problem

with common-mode interference. The second line of defense is a common-mode choke on the antenna feed line — try this first in a cable-television installation.

These two filters can probably cure most cases of TVI!

The slide shows a "bulletproof" installation. If this doesn't cure the problem, the TV circuitry is picking up your signal directly. In that case, don't try to fix it yourself — it

is a problem for the TV manufacturer.



Al Penney
VO1NO

Cable TV

- Long coax cable can act as antenna in common mode, so ferrite chokes may work.
- If not, RF may enter TV circuits directly – nothing you can do to correct it.
- Cable uses over-the-air frequencies however, so if cable system leaks, **RF can also get in**!
- If interference occurs only on **certain channels** when using **VHF/UHF transmitters**, suspect **signal ingress**.
- This may be a cable company responsibility.

Al Penney
VO1NO

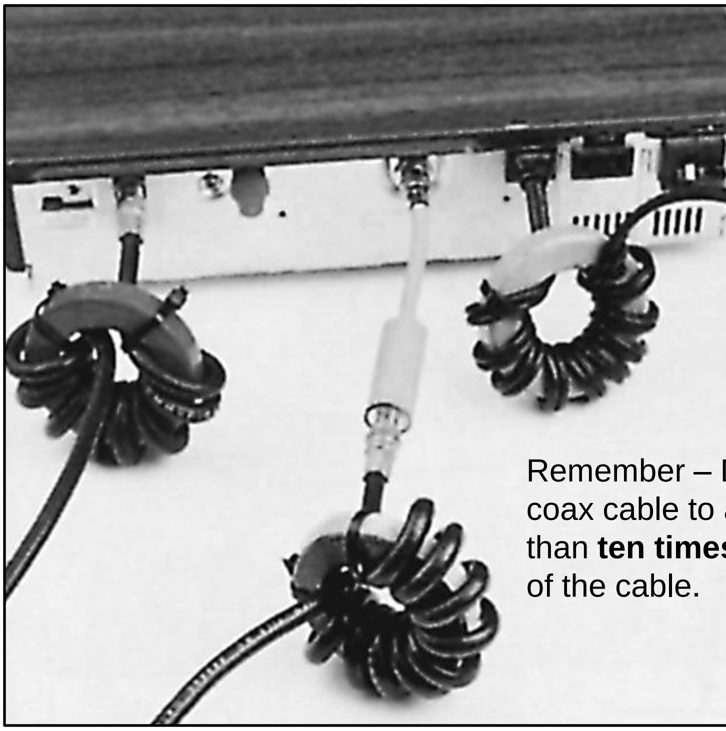
Cable TV

Cable TV has been a blessing and a curse for Amateur Radio TVI problems. On the plus side, the cable delivers a strong, consistent signal to the TV receiver. It is also (in theory) a shielded system, so an external signal can't get in and cause trouble. On the minus side, the cable forms a large, long-wire antenna that can pick up lots of external signals on its shield (in the common mode). Many TVs and VCRs and even some cable set-top converters are easily overloaded by such common-mode signals.

Leakage into a cable-TV system is called ingress. Leakage out is called egress. If the cable isn't leaking, there should be no external signals getting inside the cable. So, an in-line filter such as a high-pass filter is not usually necessary. For a cable-connected TV, the first line of defense is a common-mode choke. Only in rare cases is a high-pass filter necessary. It is important to remember this, because if your neighbor has several TVs connected to cable and you suggest the wrong filter (at $15 each), you may have a personal diplomacy problem of a whole new dimension.

A previous slide shows a bulletproof installation for cable TV. (The high-pass filter is usually not needed.) If all of the cures shown have been tried, the interference probably results from direct pickup inside the TV. In this case, contact the TV manufacturer.

Interference to cable-TV installations from VHF transmitters is a special case. Cable TV uses frequencies allocated to over-the-air services, such as Amateur Radio. When the cable shielding is less than perfect, interference can result. Contact the cable company; it may be their responsibility to locate and correct the problem. The cable company is not responsible, however, for leakage occurring in customer-owned, cable-ready equipment that is tuned to the same frequency as the over-the-air signal. If there is interference to a cable-TV installation, the cable company should be able to demonstrate interference- free reception when using a cable-company supplied set-top converter.



Remember – Do not bend coax cable to a radius less than **ten times** the diameter of the cable.

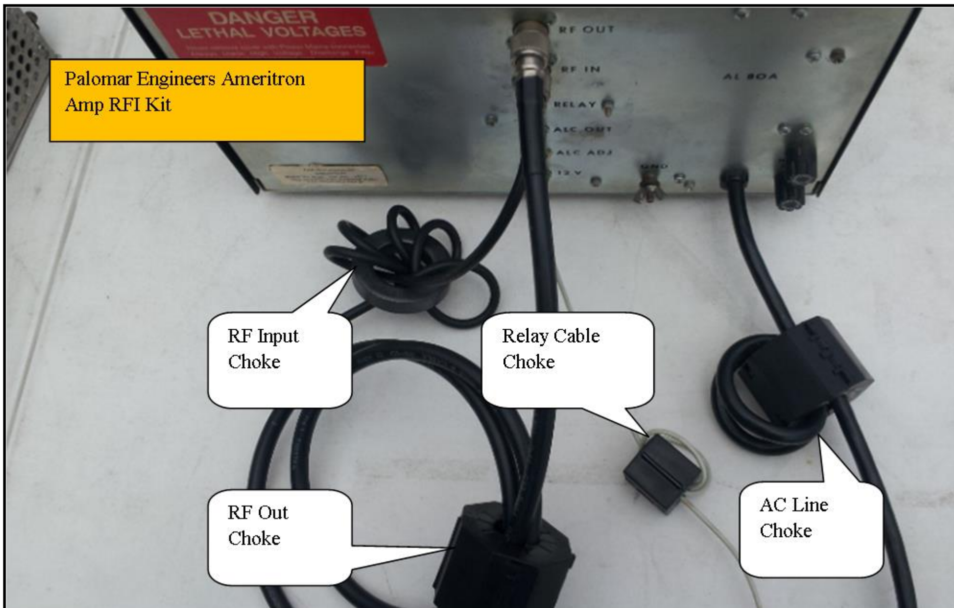
Al Penney
VO1NO

Al Penney
VO1NO

Al Penney
VO1NO

Snap-On Ferrites

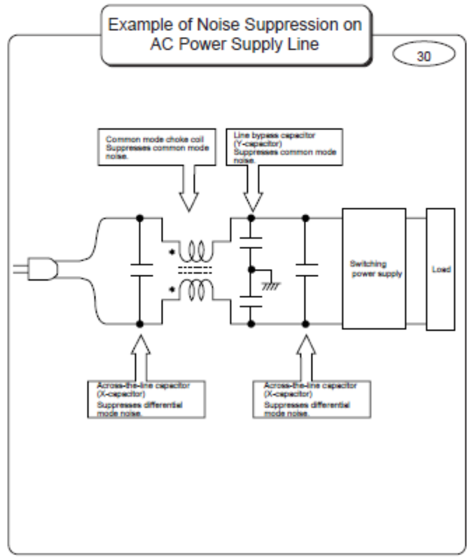
Al Penney
VO1NO



Al Penney
VO1NO

AC Line Filters

- Some incorporate **both** Common and Differential mode filters.
- Eliminate signals from traveling on AC power lines.
- Often incorporated into AC lines on **Switching Power Supplies.**



Al Penney
VO1NO

The above drawing shows an example of noise suppression on an AC power supply line.

Common mode noise is suppressed by using a common mode choke coil and capacitor (line bypass capacitor or Y-capacitor) installed between each line and the metallic casing. The Y-capacitor returns

noise to the noise source in the following order; Y-capacitor, metallic casing, stray capacitance, noise source.

Differential mode noise is suppressed by installing capacitors(X capacitors) across the supply line.

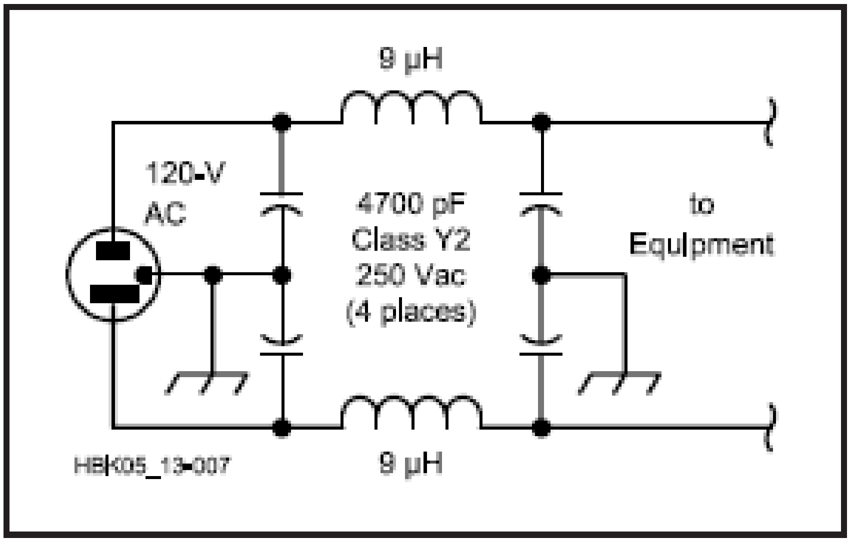


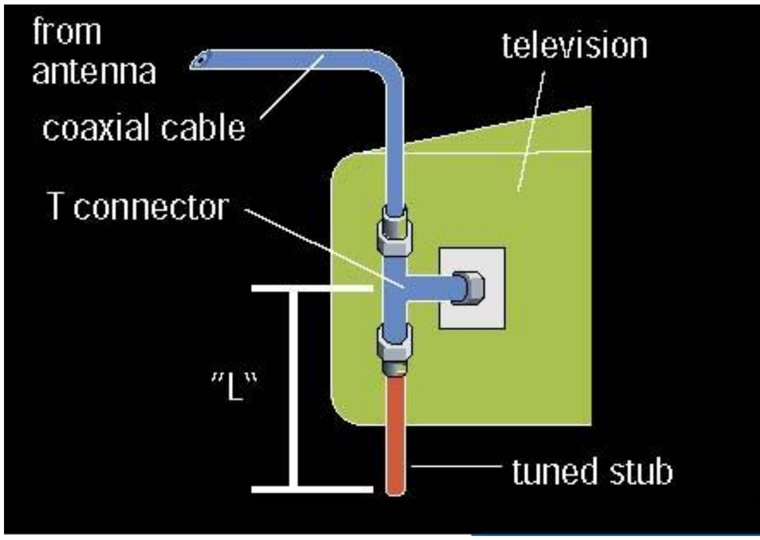
Fig 13.7 — A "brute-force" ac-line filter.

Al Penney
VO1NO

AC-line filters, sometimes called "brute-force" filters, are used to filter RF energy from power lines. A schematic is shown above. Only *ac-rated* capacitors as specified in Fig 13.7 should be used for the filter. These RFI capacitors must be used in applications where a hazard could be present to a person who touches the associated equipment — if such a capacitor were to fail. Y-Class capacitors are designed for connection between power lines and from line to ground. There are several sub-classes of Y-class capacitors, Y2 being the most common. Y2 capacitors are rated for nominal working voltages less than or equal to 250 Vac. Their peak impulse voltage rating is considerably higher however, up to 5 kV.

Al Penney
VO1NO

Quarter Wave Stub Trap



Penney
VO1NO

A Wave Trap or Quarter Wave Stub Trap can prevent signals of the design frequency from getting into the receiver.

HOMEMADE FILTER

Quarter-wave tuned stub (notch filter)

A short piece of feed line, cut to the correct length and connected in conjunction with the television receiver's antenna feed line, displays surprising characteristics. The short length of cable is frequency

selective and can be used to eliminate an interfering signal by shorting it out. Such short lengths of transmission line used as filters are called stubs. It should be noted that while the stub reduces the strength of the undesired signal, it will also weaken, to a lesser extent, TV signals nearby. A switch can also be added to use the set with or without the stub. These stubs can also be connected to booster amplifier or distribution amplifier input terminals.

For interference from an FM radio station, the initial length of the stub must be 61 cm for RG-59/U cable and 74 cm for 300 ohm twin lead wire.

Half-wave tuned stub

Half-wave tuned stubs, also made of the same type of cable as it is attached to, is twice the length of a quarter-wave length stub, and has its dangling end wires shorted together.

Ground Loops

- Grounding equipment together in a **loop** can cause it to act like an **antenna**, leading to RFI and EMI.
- Equipment should be grounded at a **single point** as shown in the bottom diagram.

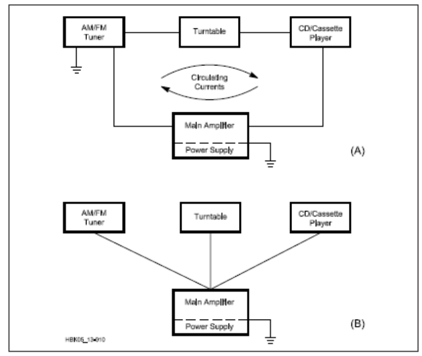


Fig 13.10 — A shows a stereo system grounded as an undesirable "ground loop." B is the proper way to ground a multiple-component system.

Al Penney
VO1NO

Ground Loops

All of these station grounds can form a large ground loop. This loop can act as a large loop antenna, with increased susceptibility to lightning or EMI problems.

The figure shows a ground loop and a proper single-point ground system.

Stereo and other Audio Systems

- SSB, AM and CW signals can often be heard on audio systems.
- SSB and AM sound muffled, CW sounds like clicks or humming noise.
- **Audio Rectification** taking place in a transistor with speaker leads acting like an antenna.
- Use a common mode choke on the speaker lines to cure.

Al Penney
VO1NO

Other Audio Devices

Other audio devices, such as stereos, intercoms and public-address systems can also pick up and detect strong nearby transmitters. The FCC considers these non-radio devices and does not protect them from licensed radio transmitters that may interfere with their operation.

Use the standard troubleshooting techniques discussed earlier in this chapter to isolate problems. In a multi-component stereo system, for example, you must determine what combination of components is involved with the problem. First, disconnect all auxiliary components to determine if there is a problem with the main receiver/amplifier. (Long speaker/interconnect cables are prime suspects.)

Stereos — If the problem remains with the main amplifier isolated, determine if the interference level is affected by the volume control. If so, the interference is getting into the circuit *before* the volume control, usually through accessory wiring. If the volume control has no effect on the level of the interfering sound, the interference is getting in *after* the control, usually through speaker wires.

Speaker wires are often resonant on the HF bands. In addition, they are often connected directly to the output transistors, where RF can be detected. Most amplifier designs use a negative feedback loop to improve fidelity. This loop can conduct the detected RF signal back to the high gain stages of the amplifier. The combination of all of these factors makes the speaker leads the usual indirect cause of interference to audio amplifiers. There is a simple test that will help determine if the interfering signal is being coupled into the amplifier by the speaker leads. Temporarily disconnect the speaker leads from the amplifier, and plug in a test set of headphones with short leads. If there is no interference with the headphones, filtering the speaker leads will cure the problem.

RF signals entering in a system and being rectified can interfere seriously. That has been classically the case of audio noise in speakers because of mobile phones using TDMA technology. The problem is now very common in products with wireless RF functionality in products with audio areas.

Audio rectification is a common EMI problem I have found several times in my troubleshooting experience. This problem is related to a high frequency signal affecting a low frequency system (supply, bias points, speakers, microphones, and audio circuits, etc.)

The high frequency signal is radiated from a nearby intended transmitter such as single-sideband phones, amateur radio, AM broadcast stations, walkie talkies, etc., or unintended sources as turn ON-OFF in motors, lighting, ESD, etc.

The effect can be detected usually as a distortion in the victim signal, on-and-off humming or clicking. Do you remember the noise from the speakers of your computer when your phone is in the vicinity?: "tac-tac-tac"

Speaker Lead Common Mode Choke

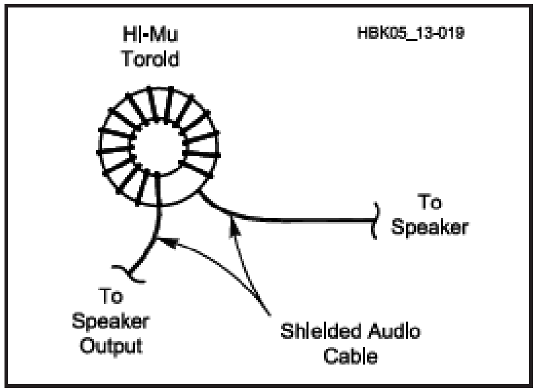


Fig 13.19 — This is how to make a speaker-lead common-mode choke. Be sure to use the correct ferrite material.

Al Penney
VO1NO

The best way to eliminate RF signals from speaker leads is with common-mode chokes. **The slide** shows how to wrap speaker wires around an FT-140-43 ferrite core to cure speaker-lead EMI. Use the correct core material for the job. See the information about common-mode chokes earlier in this chapter.

Speaker Lead LC Filter

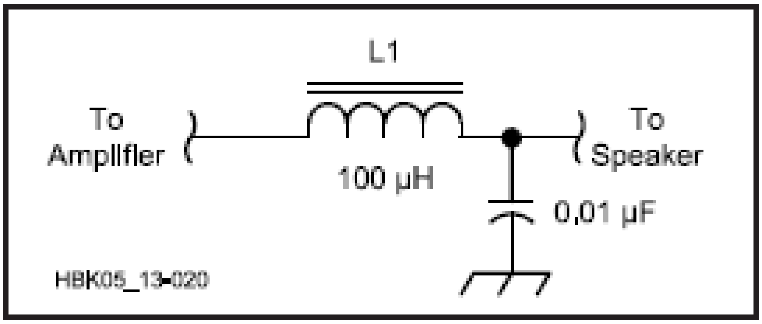
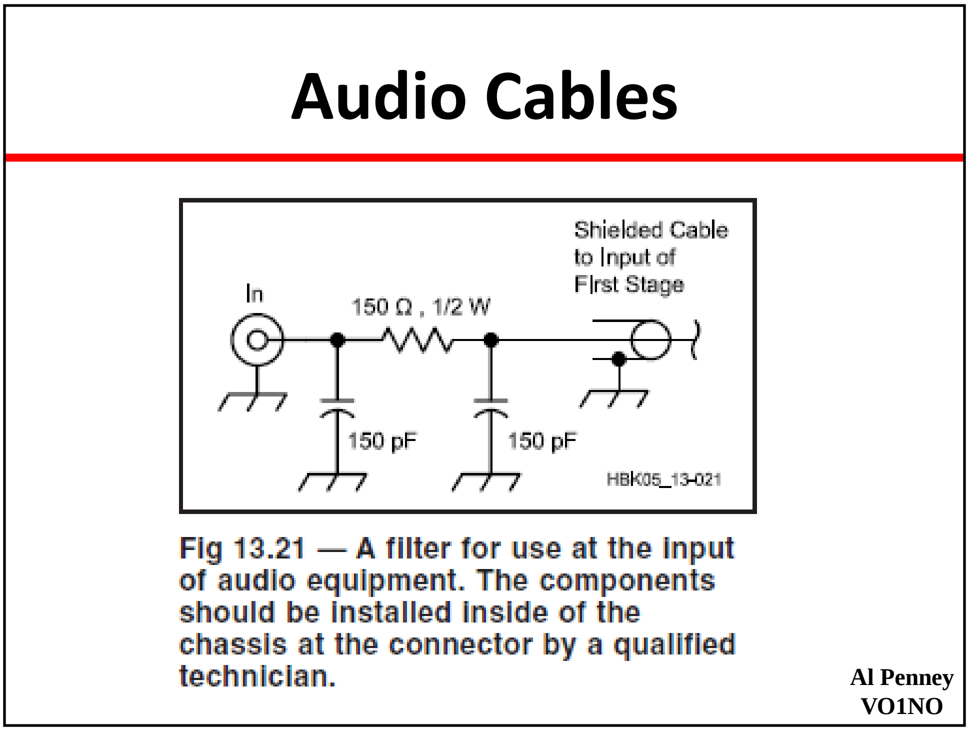


Fig 13.20 — An LC filter for speaker leads.

Al Penney
VO1NO

Another way to cure speaker-lead interference is with an LC filter as shown



Interconnect cables can couple interfering signals into an amplifier or accessories. The easiest cure here is also a common-mode choke. However, it may also be necessary to add a differential mode filter to the input of the amplifier or accessory. **The slide** shows a home-brew version of such a filter.

Intercoms and Public-Address Systems

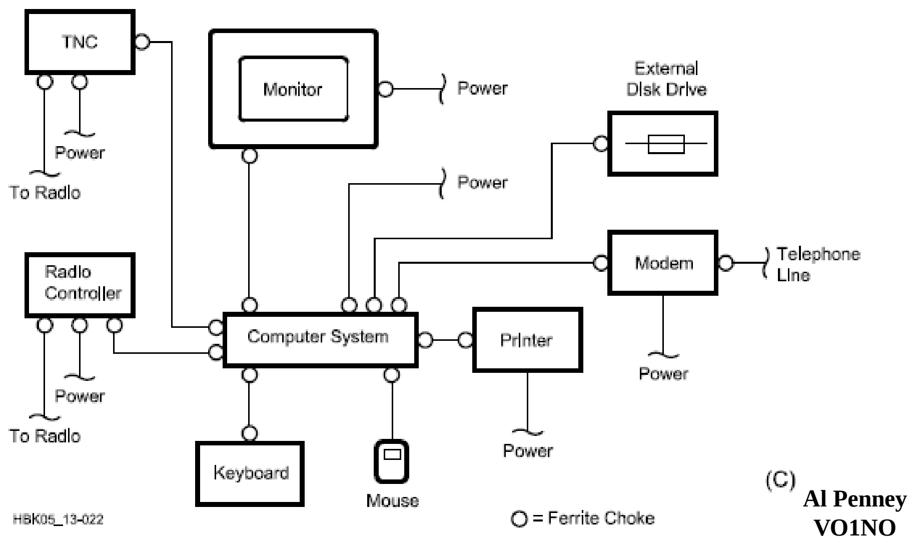
— All of these problems also apply to intercoms, public-address (PA) systems and similar devices. These systems usually have long speaker leads or interconnect cables that can pick up a lot of RF energy from a nearby transmitter. The cures discussed above do apply to these systems, but you may also need to contact the manufacturer to see if they have any additional, specific information.

Warning: Bypassing Speaker Leads

Older amateur literature might tell you to put a 0.01-µF capacitor across the speaker terminals to cure speaker-lead interference. *Don't do this!* Some modern solid-state amplifiers can break into a destructive, full-power, sometimes ultrasonic oscillation if they are connected to a highly capacitive load. If you do this to your neighbor's amplifier, you will have a whole new kind of personal diplomacy problem! *— Ed Hare, W1RFI, ARRL Laboratory Supervisor*

Al Penney
VO1NO

Computer EMI



Computers and Other Unlicensed RF Sources

Computers and microprocessors can be sources, or victims, of interference. These devices contain oscillators that can, and do, radiate RF energy. In addition, the internal

functions of a computer generate different frequencies, based on the various data rates as software is executed. All of these signals are digital — with fast rise and fall times

that are rich in harmonics.

Don't just think "computer" when thinking of computer systems. Many household appliances contain microprocessors: digital clocks, video games, calculators and more.

If you find that your computer system is interfering with your radio (not uncommon in this digital-radio age), start by simplifying the problem. Temporarily switch

off as many peripherals as possible and disconnect their cables from the back of the computer. If possible, use just the computer, keyboard and monitor. This test

may indicate one or more peripherals as the source of the interference.

When seeking cures, first ensure that all interconnection cables are shielded. Replace any unshielded cables with well shielded ones; this often significantly

reduces RF noise from computer systems. The shield must also be terminated properly at the connectors. Unfortunately, quite often the only way to find out is to

take it apart. The second line of defense is the common-mode choke, made from a ferrite toroid. The toroids should be installed as close to the computer and/or

peripheral device as practical. **The slide** shows the location of common-mode chokes in a complete computer system where both the computer and peripherals

are noisy.

In some cases, a switching power supply may be a source of interference. A common-mode choke and/or ac-line filter may cure this problem. In extreme cases

of computer interference you may need to improve the shielding of the computer. Refer to *The ARRL RFI Book* for more information about how to do this. Don't

forget that some peripherals (such as modems) are connected to the phone line, so you may need to treat them like telephones.

Telephone RFI

Al Penney
VO1NO

WHAT IS RFI? **Radio Frequency Interference** (RFI) is one of the hardest problems to solve on telephone systems. You can't see it, it may not always be there, and there is sometimes no rhyme or reason for what's happening to be happening.

In general, RFI is picked up by a component of the telephone or system that's "tuned", by coincidence, to the frequency of RFI. Whether it's a diode, transistor or even a bad solder joint, something is acting like a radio receiver, demodulating the RF signal into audio. Once RF is turned into audio, you can't filter it out (since you'd also have to filter out the conversation!).

The idea behind an RF filter is to stop the piece of wire that's acting like an antenna from bringing the radio signal into the part that's demodulating the signal. Just like on a radio or TV, if you remove the antenna, the radio signal goes away. An RF filter simply notches out a portion of the frequency spectrum, so it can't get through the filter to the part that's demodulating the RF. The filter allows the rest of the frequency spectrum to flow through the filter.

Our **RF Filters** are inductors, or chokes. They are simply wire wrapped around the proper inductive (toroid) core material, which blocks a particular frequency range from getting past the **Filter** (it *sounds* simple, but they are *very difficult* to engineer). Because there are no other components, and they're entirely passive, they don't interfere with electronic or digital telephones when placed on the line cord, or even with Ethernet when used in-series with a computer/hub/switch. While it's possible to build an active filter with more components that would notch out a larger or deeper portion of the frequency spectrum, it would not be usable on a digital or electronic phone since it would change the electrical characteristics of the pair (screwing up the power and data going to the phone).

RFI is usually worse when it's closer to the source of the radio transmission. If you see a big radio tower out the window when you're putting in a new phone system, I would expect to have some RF problems once you get the system up and running. There are no brands of phone systems that are immune to RF, and they all can get RFI - analog or digital.

Telephones

Telephones have probably become the number one interference problem of Amateur Radio. However, most cases of telephone interference can be cured by correcting any installation defects and installing telephone EMI filters where needed.

Telephones can improperly function as radio receivers. There are devices inside many telephones that act like diodes. When such a telephone is connected to the telephone wiring (a large antenna), an AM radio receiver can be formed. When a nearby transmitter goes on the air, these telephones can be affected.

Troubleshooting techniques were discussed earlier in the chapter. The suggestion to simplify the problem applies especially to telephone interference. Disconnect all telephones except one, right at the service entrance if possible, and start troubleshooting the problem there. If any one device, or bad connection in the phone system, detects RF and puts the detected signal back onto the phone line as audio, that audio cannot be removed with filters. Once the RF has been detected and turned into audio, it cannot be filtered out because the interference is at the same frequency as the desired audio signal. To affect a cure, you must locate the detection point and correct the problem there.

The telephone company lightning arrestor may be defective. Defective arrestors can act like diodes, rectifying any nearby RF energy. Telephone-line amplifiers or other electronic equipment may also be at fault. Leave the telephone company equipment to the experts, however. There are important safety issues that are the sole responsibility of the telephone company.

Inspect the installation. Years of exposure in damp basements, walls or crawl spaces may have caused deterioration. Be suspicious of anything that is corroded or discolored. In many cases, homeowners have installed their own telephone wiring, often using substandard wiring. If you find sections of telephone wiring made from nonstandard cable, replace it with standard twisted-pair wire. Radio Shack, among others, sells several kinds of telephone wire.

Next, evaluate each of the telephone instruments. If you find a susceptible telephone, install a telephone EMI filter on that telephone. Several *QST* advertisers sell small, attractive telephone EMI filters. If you determine that you have interference only when you operate on one particular ham band, the telephone wiring is probably resonant on that band. If possible, install a few strategically placed inline telephone EMI filters to break up the resonance.

Telephone Accessories — Answering machines, fax machines and some alarm systems are also prone to interference problems. All of the troubleshooting techniques and cures that apply to telephones also apply to these telephone devices. In addition, many of these devices connect to the ac mains. Try a common-mode choke and/or ac-line filter on the power cord (which may be an ac cord set, a small transformer or power supply).

Electrical Noise

- Often caused by **electrical appliances** & **power lines**.
- Usually sounds like a **60/120 Hz buzz** on RX.
- Should vary with **speed of motor**.
- Vary by weather – then outside.
- Vary by time of day – then lifestyle activities.
- AC line filter and/or common mode chokes may solve problem.
- If power line arcing, contact power company.

Al Penney
VO1NO

Electrical Noise

Many electrical appliances and power lines can generate electrical noise. On a receiver, electrical noise usually sounds like a rough buzz, heard across a wide frequency range. The buzz will either have a strong 60- or 120-Hz component, or its pitch will vary with the speed of a motor that generates the noise. The appearance of electrical noise on a television set is shown in the TVI section of this chapter. This kind of noise can come from power lines, electrical motors or switches, to name just a few.

Here is one quick diagnostic trick — if electrical noise seems to come and go with the weather, the source is probably outside, usually on the power lines. If electrical noise varies with the time of day, it is usually related to what people are doing, so look to your own, or our neighbors′, house and lifestyle. *The ARRL RFI Book* describes techniques for locating RFI sources.

Filters usually cure electrical noise. At its source, the noise can usually be filtered with a differential-mode filter. A differential- mode filter can be as simple as a 0.01-⌠F ac-rated capacitor, such as Panasonic part ECQ-U2A103MN, or it can be a pi-section AC line filter.

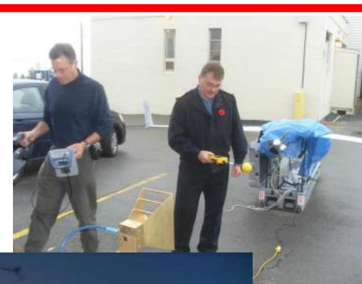
For removing signals that arrive via power lines, a common-mode choke is usually the best defense. Wrap about 10 turns of the ac-power cord around an FT-240-43 ferrite core; do this as close as possible to the device you are trying to protect.

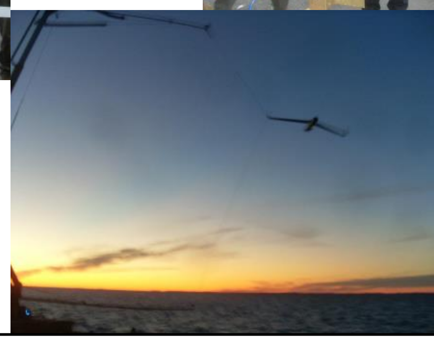
Electrical noise can also indicate a dangerous electrical condition that needs to be corrected. The ARRL has recorded several cases where defective or arcing doorbell transformers caused widespread neighborhood electrical interference. This subject is well covered in the *The ARRLRFI Book*.

EMI can affect Anything!

Al Penney
VO1NO

ScanEagle UAV EMI Trials





Industry Canada’s Position

- Consumers should:
  - Insist manufacturer’s design equipment to operate in a dense RF environment; and
  - Ensure equipment is set up and operated properly.
- Radio users should:
  - Accept the reality that high power radio transmitters, in urban areas, are likely to interfere with radio-sensitive devices; and
  - Consider methods of reducing the levels of RF energy, to which they expose their neighbours' electronic items

Al Penney
VO1NO

Industry Canada's Position

- Complainant must take a number of steps to resolve the issue:
  - Cooperate with Radio Operator;
  - Contact manufacturer of affected equipment to seek assistance;
  - Use self-help info offered by IC; and
  - Seek technical assistance if unable to help themselves.
- Only then will IC intervene.

Al Penney
VO1NO

Industry Canada’s Position

- Radio Operator:
  - Encouraged to work with complainants in resolving problems without recourse IC.
  - Failure to provide such cooperation may result in IC imposing additional terms and conditions upon the users’ authorization to operate radio apparatus.

Al Penney
VO1NO

Industry Canada’s Position

- In the event of interference to a neighbor’s radio receiver, stereo, VCR, TV set or other "radio sensitive equipment" capable of receiving RF signals, if the **field strength of the amateur station is below 1.83 volts per meter**, it will be deemed that the affected equipment’s **lack of immunity is the cause**. However if the field strength of the amateur station **exceeds 1.83 volts per meter**, it will be deemed that the **amateur’s transmission is the cause of the problem**.

Al Penney
VO1NO

Industry Canada's Position

- **Radio-sensitive** equipment is considered to be "any device, machinery or equipment, other than radio apparatus, the use or functioning of which is, or can be, **adversely affected by radiocommunications emissions".** These may include electronic organs, microwave ovens, furnace controllers and a host of other non-radio type of equipment.

Al Penney
VO1NO

Industry Canada's Position

- Where interference to the reception of radiocommunications is **caused by the operation of an amateur station**, the Minister may require that **necessary steps** for the prevention of the interference be taken by the **radio amateur**.

Al Penney
VO1NO

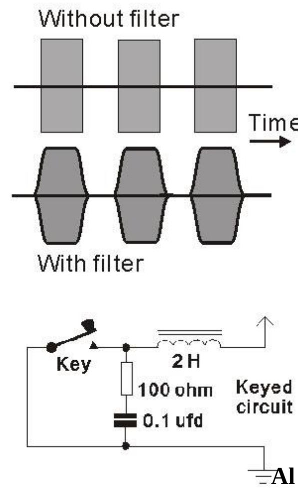
Interference to Other Hams

- Three primary issues:
  - **Key Clicks**: Transmitter turns on and off too rapidly during Morse transmissions, causing signal to occupy **too wide a bandwidth**.
  - **Chirp**: **Voltage fluctuations** when transmitter is keyed during Morse transmissions, cause **VFO's frequency to vary**, resulting in an audible chirp in received signal.
  - **Splatter** caused by setting **microphone gain** or amplifier drive too high.

Al Penney
VO1NO

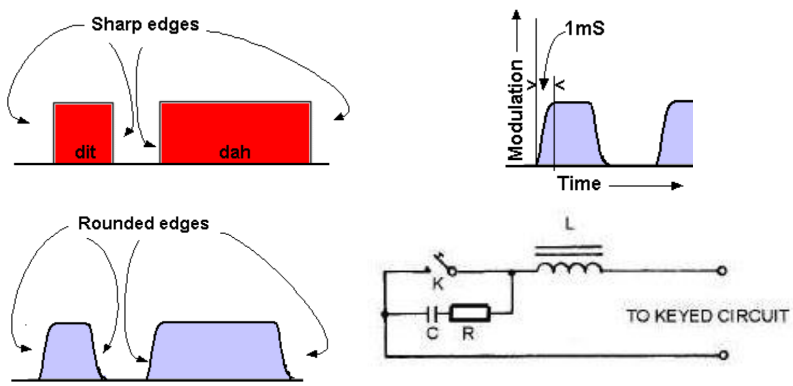
Key Clicks

- Usually not a problem with modern radios.
- For older radios a key click filter can help.
- Indicated with addition of "K" to signal report i.e.: 599K



Al Penney
VO1NO

Key Clicks



Al Penney
VO1NO

KEY CLICKS

When you key the letter A dit dah you have a very sharp leading and trailing edges to the wave form, if you looked at it on an oscilloscope as shown at the top.

The sharp edge occurs as the carrier goes from zero to maximum in the shortest possible time and is very much like an AM signal that has maximum modulation applied. With the very sharp edge and very short rise time it generates noisy sidebands which are the clicks that can be heard.

It is therefore the transition from zero to maximum carrier in the shortest possible time that causes the key clicks.

The way to remove the key clicks to the "soften the keying." This is done by having a less sharp and some what more rounded wave form.

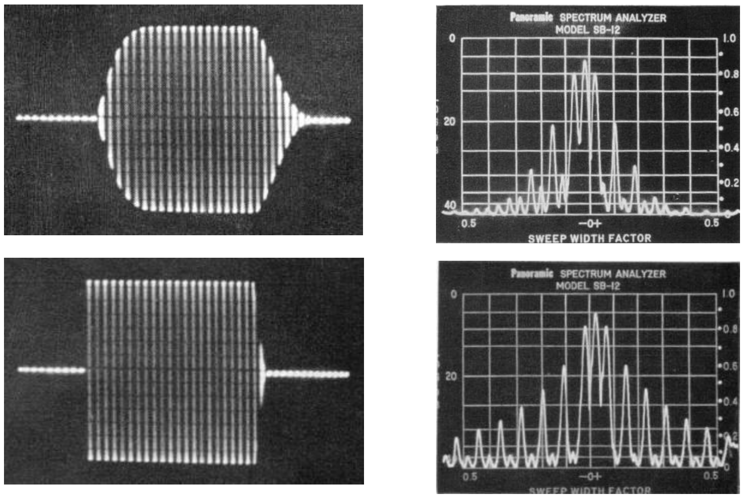
The leading and trailing edges are softened / more rounded - if you make it too soft you would loose intelligibility of the Morse character .

A rise and fall time of about 1mS (1 milli second) might be considered a reasonable average but it all depends upon the equipment, as the softening and hardening of characters also depends upon things like decoupling in the bias circuit.

If you wanted to construct a transmitter and avoid key clicks you would need to look at the wave form on an oscilloscope with the scope connectors clipped across a dummy load being fed from the transmitter - on very low power - you can observe the wave form and then change the keying characteristics by using capacitors or a key click filter of a resistor and capacitor or a choke resistor and capacitor. There are various combinations depending upon the amount of current that you are keying.

An example of a Key Click filter circuit is illustrated above.

Key Clicks



Al Penney
VO1NO

Fig. 4-A (left) - Shaped dot generated at a 46-baud rate with approximately 5·millisecond rise and decay times. Vertical lines are from a 1000-cycle signal applied to the Z axis for timing.

Fig. 4-B (right) - The corresponding frequency spectrum as shown by a Panoramic analyzer. Distance between vertical lines is 50 cycles, for a total bandwidth of 500 cycles for the entire picture. Decibel scale at the left is with reference to the key-down signal amplitude which was set at 0 db. in this and the spectrum plots of Fig. 6. The fundamental frequency components are 23 cycles on either side of the carrier frequency, which appears slightly to the left of the vertical zero axis. Note that the odd harmonics of 23 cycles are predominant, the even harmonics being relatively small. The 3rd harmonics are 20 db. down and the 5th harmonics are about 28 db. down. Higher-order harmonics are practically negligible. With 7-ms. rise and decay times the 5th harmonics are down 30 db.

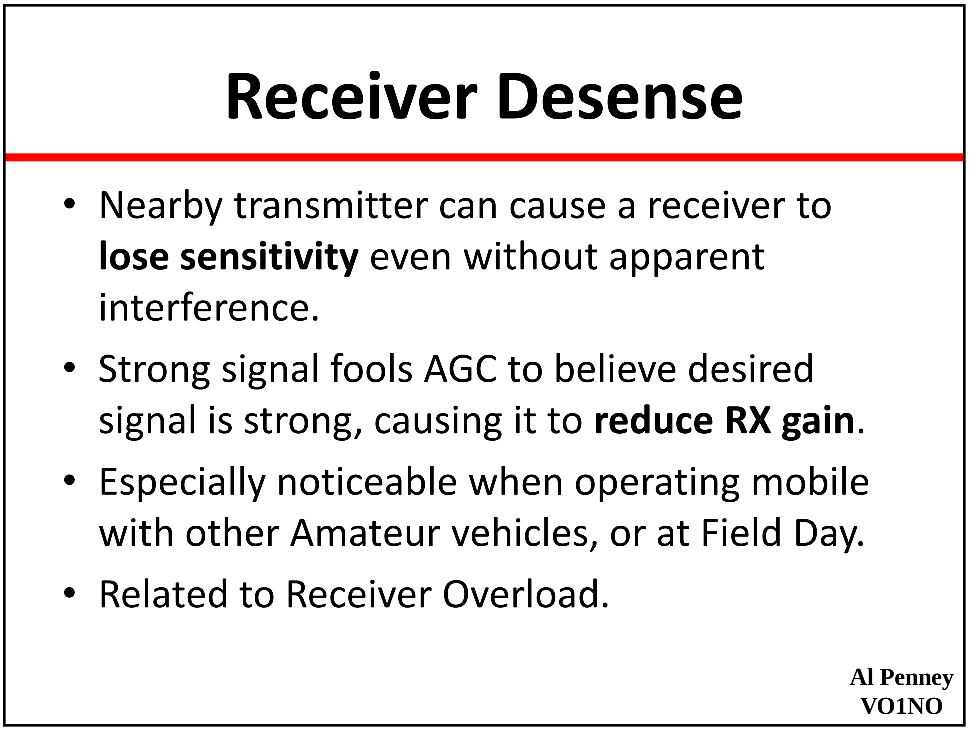
Fig. 6-A - Dot with no intentional shaping; conditions otherwise the same as in Fig. 4. There is a finite decay time inherent in the keying system, but the rise time is quite short.

Fig. 6-B - Corresponding frequency spectrum over a 500-cycle bandwidth; carrier frequency slightly to the right of the vertical zero axis.

Chirp

- **Voltage "sags"** when transmitter is keyed, causing transmitter **frequency to shift slightly** until voltage level recovers.
- Cure is to use a power supply and cabling that can handle the load **without** voltage sag.
- Indicated by addition of a "C" to the signal report i.e.: 599C

Al Penney
VO1NO

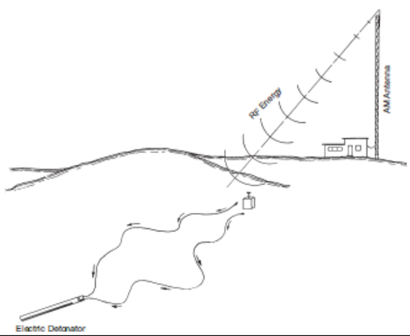


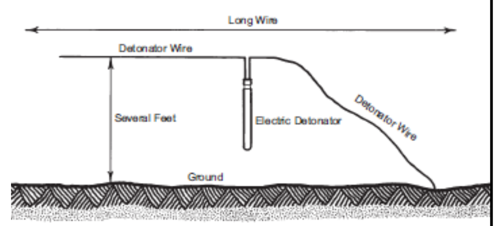
In telecommunications, **desensitization** (also known as **receiver blocking**) is a form of electromagnetic interference where a radio receiver is unable to receive a weak radio signal that it might otherwise be able to receive when there is no interference. This is caused by a nearby transmitter with a strong signal on a close frequency, which overloads the receiver and makes it unable to fully receive the desired signal.


DANGER
BLASTING AHEAD
PLEASE TURN OFF
RADIO TRANSMITTER
PROTEXPLO
450 623-6797
www.protexplo.ca

Explosive Safety

- Yes – transmitters **CAN detonate** explosives!
- RF can be picked up by detonating wire, which can accidentally trigger the wireless Electro-Explosive Devices used to initiate explosives.





Al Penney
VO1NO

Initiation of Electric Detonators by Radio Frequency Energy

The possibility of premature explosions of electric detonators due to RF energy is remote. Each year throughout North America approximately 100 million such detonators are used with few mishaps. However, there have been authenticated cases in which detonators were prematurely initiated by RF transmission to the detonator wires. Subsequent investigations revealed that the instances would not have occurred if proper safe distances from the RF sources had been maintained.

How RF Energy Initiates Electric Detonators

If the electric detonator wires are located in a strong RF field (near a transmitter that is radiating RF power), the usually insulated but unshielded leg wires or circuit wires will act as an antenna similar to that on a radio or TV set. That is true whether the circuit wires are connected to a blasting machine or not, or whether they are shunted (short circuited ends) or not shunted (open ends). This antenna will absorb RF energy from the transmitter RF field, and the electric current transmitted to the detonator wires will flow into the detonator. (See Figure 1.) Depending on the strength of the RF field and the antenna configuration formed by the detonator wires and its orientation, sufficient RF energy may be induced in the wires to fire the electric detonator.


Questions?
Al Penney
VO1NO

For Next Class:

- Review Chapter 15 of Basic Study Guide;
- Read Chapter 16 of Basic Study Guide; and
- Go through the Question Bank.
- Remember – the end of the course is approaching!

Al Penney
VO1NO

Review Question 1

What is meant by receiver overload?

• Too much current from the power supply

• Too much voltage from the power supply

• Interference caused by strong signals from a nearby transmitter

• Interference caused by turning the volume up too high

Al Penney
VO1NO

Review Question 1

What is meant by receiver overload?

• Too much current from the power supply

• Too much voltage from the power supply

• Interference caused by strong signals from a nearby transmitter

• Interference caused by turning the volume up too high

< Interference caused by strong signals from a nearby transmitter >

Al Penney
VO1NO

Review Question 2

What is one way to tell if radio frequency interference to a receiver is caused by front-end overload?

• If the interference is about the same no matter what frequency is used for the transmitter

• If grounding the receiver makes the problem worse

• If connecting a low pass filter to the receiver greatly cuts down the interference

• If connecting a low pass filter to the transmitter greatly cuts down the interference

Al Penney
VO1NO

Review Question 2

What is one way to tell if radio frequency interference to a receiver is caused by front-end overload?

• If the interference is about the same no matter what frequency is used for the transmitter

• If grounding the receiver makes the problem worse

• If connecting a low pass filter to the receiver greatly cuts down the interference

• If connecting a low pass filter to the transmitter greatly cuts down the interference

< If the interference is about the same no matter what frequency is used for the transmitter >

Al Penney
VO1NO

Review Question 3

If a neighbour reports television interference whenever you transmit, no matter what band you use, what is probably the cause of the interference?

- Receiver VR tube discharge
- Too little transmitter harmonic suppression
- Receiver overload
- Incorrect antenna length

Al Penney
VO1NO

Review Question 3

If a neighbour reports television interference whenever you transmit, no matter what band you use, what is probably the cause of the interference?

- Receiver VR tube discharge
- Too little transmitter harmonic suppression
- Receiver overload
- Incorrect antenna length

< Receiver overload >

Al Penney
VO1NO

Review Question 4

What type of filter should be connected to a TV receiver as the first step in trying to prevent RF overload from an amateur HF station transmission?

- Low-pass
- Band-pass
- No filter
- High-pass

Al Penney
VO1NO

Review Question 4

What type of filter should be connected to a TV receiver as the first step in trying to prevent RF overload from an amateur HF station transmission?

- Low-pass
- Band-pass
- No filter
- High-pass

< High-pass >

Al Penney
VO1NO

Review Question 5

During a club ARRL Field Day outing, reception on the 20 m SSB station is compromised every time the 20 m CW station is on the air. What might cause such interference?

- Receiver desensitization
- Both stations are fed from the same generator
- Improper station grounding
- Harmonic radiation

Al Penney
VO1NO

Review Question 5

During a club ARRL Field Day outing, reception on the 20 m SSB station is compromised every time the 20 m CW station is on the air. What might cause such interference?

- Receiver desensitization
- Both stations are fed from the same generator
- Improper station grounding
- Harmonic radiation

< Receiver desensitization >

Also called receiver overload.

Al Penney
VO1NO

Review Question 6

Inter-modulation in a broadcast receiver by a nearby transmitter would be noticed in the receiver as:

- the undesired signal in the background of the desired signal
- interference only when a broadcast signal is tuned
- distortion on transmitted voice peaks
- interference continuously across the dial

Al Penney
VO1NO

Review Question 6

Inter-modulation in a broadcast receiver by a nearby transmitter would be noticed in the receiver as:

• the undesired signal in the background of the desired signal

• interference only when a broadcast signal is tuned

• distortion on transmitted voice peaks

• interference continuously across the dial

< the undesired signal in the background of the desired signal >

Al Penney
VO1NO

Review Question 7

You have connected your hand-held VHF transceiver to an outside gain antenna. You now hear a mixture of signals together with different modulation on your desired frequency. What is the nature of this interference?

- Audio stage intermodulation interference
- Receiver intermodulation interference
- Harmonic interference from other stations
- Audio stage overload interference

Al Penney
VO1NO

Review Question 7

You have connected your hand-held VHF transceiver to an outside gain antenna. You now hear a mixture of signals together with different modulation on your desired frequency. What is the nature of this interference?

- Audio stage intermodulation interference
- Receiver intermodulation interference
- Harmonic interference from other stations
- Audio stage overload interference

< Receiver intermodulation interference >

Al Penney
VO1NO

Review Question 8

Two mobile stations are traveling along the same road in close proximity to each other and having trouble communicating through a local repeater. Why may it be necessary to use simplex operation to communicate between these cars?

• The strong signal of one mobile may desensitize the receiver of the other mobile receiver

• Simplex operation does not require the use of CTCSS tones

• There is less time delay using simplex operation as compared to a repeater

• There are many more simplex frequencies than repeater frequencies available

Al Penney
VO1NO

Review Question 8

Two mobile stations are traveling along the same road in close proximity to each other and having trouble communicating through a local repeater. Why may it be necessary to use simplex operation to communicate between these cars?

• The strong signal of one mobile may desensitize the receiver of the other mobile receiver

• Simplex operation does not require the use of CTCSS tones

• There is less time delay using simplex operation as compared to a repeater

• There are many more simplex frequencies than repeater frequencies available

< The strong signal of one mobile may desensitize the receiver of the other mobile receiver >

Al Penney
VO1NO

Review Question 9

A television receiver suffers interference on channel 5 (76 – 82 MHz) only when you transmit on 14 MHz. From your home you see the tower of a commercial FM station known to broadcast on 92.5 MHz. Which of these solutions would you try first?

- Insert a high pass filter at the antenna connector of the HF transmitter
- Insert a low pass filter at the antenna connector of the television set
- Insert a high pass filter at the antenna connector of the television
- Insert a low pass filter at the antenna connector of the HF transmitter

Al Penney
VO1NO

Review Question 9

< Insert a high pass filter at the antenna connector of the television >

In Bloom's Taxonomy of Educational Objectives this would be described as a "synthesis and evaluation question". You know how to answer it but you have to bring different concepts into play to answer the question but without being told how to do this. The challenge here to keep any signals out of the TV set in the range 76 – 82 MHz. One possible source of interference is a harmonic of 14 MHz. Five times 14 MHz is 70 MHz and six times 14 MHz is 84 MHz. The two harmonics are above/below channel 2. Add to this that you are a good operator and your transceiver is equipped with a Low-Pass filter so your transmitter can be ruled out as the primary source. So the culprit here is probably the FM station. One possibility is that its 92.5 MHz signal mixes with your 14 MHz signal. There will be two products, a sum of the two signals (92.5 + 14=106.5 MHz) and a difference between the two signals (92.5 – 14 = 78.5 MHz). The latter falls right in the middle of Channel 6. The solution is "Insert a high pass filter at the antenna connector of the television".

Al Penney
VO1NO

Review Question 10

How can intermodulation be reduced?

- By increasing the receiver RF gain while decreasing the AF gain
- By adjusting the passband tuning
- By installing a suitable filter at the receiver
- By using a better antenna

Al Penney
VO1NO

Review Question 10

How can intermodulation be reduced?

• By increasing the receiver RF gain while decreasing the AF gain

• By adjusting the passband tuning

• By installing a suitable filter at the receiver

• By using a better antenna

< By installing a suitable filter at the receiver >

The assumption here is that you are dealing with interference in a receiver.

Al Penney
VO1NO

Review Question 11

What devices would you install to reduce or eliminate audio-frequency interference to home entertainment systems?

- Metal-oxide varistors
- Bypass inductors
- Coils on ferrite cores
- Bypass resistors

Al Penney
VO1NO

Review Question 11

What devices would you install to reduce or eliminate audio-frequency interference to home entertainment systems?

- Metal-oxide varistors
- Bypass inductors
- Coils on ferrite cores
- Bypass resistors

< Coils on ferrite cores >

Al Penney
VO1NO

Review Question 12

What sound is heard from a public-address system if audio rectification of a nearby single sideband phone transmission occurs?

- On-and-off humming or clicking
- A steady hum whenever the transmitter’s carrier is on the air
- Distorted speech from the transmitter’s signals
- Clearly audible speech from the transmitter’s signals

Al Penney
VO1NO

Review Question 12

What sound is heard from a public-address system if audio rectification of a nearby single sideband phone transmission occurs?

• On-and-off humming or clicking

• A steady hum whenever the transmitter’s carrier is on the air

• Distorted speech from the transmitter’s signals

• Clearly audible speech from the transmitter’s signals

< Distorted speech from the transmitter’s signals >

Al Penney
VO1NO

Review Question 13

How can you minimize the possibility of audio rectification of your transmitter's signals?

- Ensure that all station equipment is properly grounded
- Install bypass capacitors on all power supply rectifiers
- Use CW only
- Use a solid-state transmitter

Al Penney
VO1NO

Review Question 13

How can you minimize the possibility of audio rectification of your transmitter's signals?

• Ensure that all station equipment is properly grounded

• Install bypass capacitors on all power supply rectifiers

• Use CW only

• Use a solid-state transmitter

< Ensure that all station equipment is properly grounded >

Al Penney
VO1NO

Review Question 14

An amateur transmitter is being heard across the entire dial of a broadcast receiver. The receiver is most probably suffering from:

- audio rectification in the receiver
- harmonics interference from the transmitter
- poor image rejection
- splatter from the transmitter

Al Penney
VO1NO

Review Question 14

An amateur transmitter is being heard across the entire dial of a broadcast receiver. The receiver is most probably suffering from:

• audio rectification in the receiver

• harmonics interference from the transmitter

• poor image rejection

• splatter from the transmitter

< audio rectification in the receiver >

Al Penney
VO1NO

Review Question 15

Your SSB HF transmissions are heard muffled on a sound system in the living room regardless of its volume setting. What causes this?

- Harmonics generated at the transmitter
- Improper filtering in the transmitter
- Lack of receiver sensitivity and selectivity
- Audio rectification of strong signals

Al Penney
VO1NO

Review Question 15

Your SSB HF transmissions are heard muffled on a sound system in the living room regardless of its volume setting. What causes this?

- Harmonics generated at the transmitter
- Improper filtering in the transmitter
- Lack of receiver sensitivity and selectivity
- Audio rectification of strong signals

< Audio rectification of strong signals >

Al Penney
VO1NO

Review Question 16

Stereo speaker leads often act as antennas to pick up RF signals. What is one method you can use to minimize this effect?

- Lengthen the leads
- Connect the speaker through an audio attenuator
- Connect a diode across the speaker
- Shorten the leads

Al Penney
VO1NO

Review Question 16

Stereo speaker leads often act as antennas to pick up RF signals. What is one method you can use to minimize this effect?

- Lengthen the leads
- Connect the speaker through an audio attenuator
- Connect a diode across the speaker
- Shorten the leads

<Shorten the leads>

Al Penney
VO1NO

Review Question 17

One method of preventing RF from entering a stereo set through the speaker leads is to wrap each of the speaker leads:

- through a ferrite core
- around a copper bar
- around an iron bar
- around a wooden dowel

Al Penney
VO1NO

Review Question 17

One method of preventing RF from entering a stereo set through the speaker leads is to wrap each of the speaker leads:

• through a ferrite core

• around a copper bar

• around an iron bar

• around a wooden dowel

< through a ferrite core >

Al Penney
VO1NO

Review Question 18

How can you prevent key-clicks?

- By increasing power
- By using a better power supply
- By sending CW more slowly
- By using a key-click filter

Al Penney
VO1NO

Review Question 18

How can you prevent key-clicks?

- By increasing power
- By using a better power supply
- By sending CW more slowly
- By using a key-click filter

< By using a key-click filter >

Al Penney
VO1NO

Review Question 19

If someone tells you that signals from your hand-held transceiver are interfering with other signals on a frequency near yours, what could be the cause?

- Your hand-held is transmitting spurious emissions
- You need a power amplifier for your hand-held
- Your hand-held has a chirp from weak batteries
- You need to turn the volume up on your hand-held

Al Penney
VO1NO

Review Question 19

If someone tells you that signals from your hand-held transceiver are interfering with other signals on a frequency near yours, what could be the cause?

- Your hand-held is transmitting spurious emissions
- You need a power amplifier for your hand-held
- Your hand-held has a chirp from weak batteries
- You need to turn the volume up on your hand-held

< Your hand-held is transmitting spurious emissions >

Al Penney
VO1NO

Review Question 20

If your transmitter sends signals outside the band where it is transmitting, what is this called?

- Side tones
- Transmitter chirping
- Off-frequency emissions
- Spurious emissions

Al Penney
VO1NO

Review Question 20

If your transmitter sends signals outside the band where it is transmitting, what is this called?

- Side tones
- Transmitter chirping
- Off-frequency emissions
- Spurious emissions

< Spurious emissions >

Al Penney
VO1NO

Review Question 21

Key-clicks, heard from a Morse code transmitter at a distant receiver, are the result of:

- changes in oscillator frequency on keying
- too sharp rise and decay times of the keyed carrier
- power supply hum modulating the carrier
- sparks emitting RF from the key contacts

Al Penney
VO1NO

Review Question 21

Key-clicks, heard from a Morse code transmitter at a distant receiver, are the result of:

• changes in oscillator frequency on keying

• too sharp rise and decay times of the keyed carrier

• power supply hum modulating the carrier

• sparks emitting RF from the key contacts

< too sharp rise and decay times of the keyed carrier >

Al Penney
VO1NO

Review Question 22

What should you do if you learn that your transmitter is causing key-clicks?

- Turn the receiver down
- Regulate the oscillator supply voltage
- Use a choke in the RF power output
- Check the keying filter and the functioning of later stages

Al Penney
VO1NO

Review Question 22

What should you do if you learn that your transmitter is causing key-clicks?

- Turn the receiver down
- Regulate the oscillator supply voltage
- Use a choke in the RF power output
- Check the keying filter and the functioning of later stages

< Check the keying filter and the functioning of later stages >

Al Penney
VO1NO

Review Question 23

A parasitic oscillation:

- is generated by parasitic elements of a Yagi beam
- does not cause any radio interference
- is produced in a transmitter oscillator stage
- is an unwanted signal developed in a transmitter

Al Penney
VO1NO

Review Question 23

A parasitic oscillation:

• is generated by parasitic elements of a Yagi beam

• does not cause any radio interference

• is produced in a transmitter oscillator stage

• is an unwanted signal developed in a transmitter

< is an unwanted signal developed in a transmitter >

Al Penney
VO1NO

Review Question 24

Parasitic oscillations in the RF power amplifier stage of a transmitter may be found:

- on harmonic frequencies
- at high frequencies only
- at low frequencies only
- at high or low frequencies

Al Penney
VO1NO

Review Question 24

Parasitic oscillations in the RF power amplifier stage of a transmitter may be found:

• on harmonic frequencies

• at high frequencies only

• at low frequencies only

• at high or low frequencies

< at high or low frequencies >

Al Penney
VO1NO

Review Question 25

If a neighbour reports television interference on one or two channels only when you transmit on 15 metres, what is probably the cause of the interference?

- TV receiver front-end overload
- Too much low pass filtering on the transmitter
- Harmonic radiation from your transmitter
- De-ionization of the ionosphere near your neighbour's TV antenna

Al Penney
VO1NO

Review Question 25

If a neighbour reports television interference on one or two channels only when you transmit on 15 metres, what is probably the cause of the interference?

- TV receiver front-end overload
- Too much low pass filtering on the transmitter
- Harmonic radiation from your transmitter
- De-ionization of the ionosphere near your neighbour’s TV antenna

< Harmonic radiation from your transmitter >

Al Penney
VO1NO

Review Question 25

The important fact here is that there is only interference on one or two channels. Say it is channel 3 and this is on 60 – 66 MHz. Check the range of interference from 15 meters.

IC also says that the interference only occurs when you are on the 15 metre band which we know lies between 21.000 and 21.450 MHz. If we might digress here, this question is very much pre-HDTV. With HDTV you cannot assume that the TV signal is on the reporting channel and therefore you cannot assume that a station reporting as channel 3 lies between 60 and 66 MHz.

For example, in the Toronto area, CKVR (Barrie) reports as channel 3 but is actually on digital channel 10 (DTV pilot carrier on 192.31 MHz). The pilot carrier generally lies 310 kHz above the lower band edge but may be offset to reduce co-channel interference. If you have TVI on an HDTV receiver your first problem would be to discover what the true frequency of the station with which you are interfering is. A good starting point is an Internet search, or try Wikipedia. Our initial position here is that harmonic interference from the transmitter is the culprit. A few sample calculations show that the third harmonic of a 15 m signal will fall between 63.00 MHz and 64.35 MHz, all of which lie in the range occupied by channel 3. Harmonic radiation from the transmitter is the most likely cause.

You might suspect another possibility, that the TV tuner is suffering from front end overload because it is too close to your transmitter. This can be eliminated because the problem would probably show up when you were on other bands, and when the TV was on other channels.

Al Penney
VO1NO

Review Question 26

What is meant by harmonic radiation?

- Signals which cause skip propagation to occur
- Unwanted signals at frequencies which are multiples of the fundamental (chosen) frequency
- Unwanted signals that are combined with a 60-Hz hum
- Unwanted signals caused by sympathetic vibrations from a nearby transmitter

Al Penney
VO1NO

Review Question 26

What is meant by harmonic radiation?

• Signals which cause skip propagation to occur

• Unwanted signals at frequencies which are multiples of the fundamental (chosen) frequency

• Unwanted signals that are combined with a 60-Hz hum

• Unwanted signals caused by sympathetic vibrations from a nearby transmitter

< Unwanted signals at frequencies which are multiples of the fundamental (chosen) frequency >

Al Penney
VO1NO

Review Question 27

What type of interference may come from a multi-band antenna connected to a poorly tuned transmitter?

- Harmonic radiation
- Parasitic excitation
- Intermodulation
- Auroral distortion

Al Penney
VO1NO

Review Question 27

What type of interference may come from a multi-band antenna connected to a poorly tuned transmitter?

- Harmonic radiation
- Parasitic excitation
- Intermodulation
- Auroral distortion

< Harmonic radiation >

Al Penney
VO1NO

Review Question 28

If you are told your station was heard on 21 375 kHz, but at the time you were operating on 7125 kHz, what is one reason this could happen?

• Your transmitter was radiating harmonic signals

• Your transmitter's power-supply filter choke was bad

• You were sending CW too fast

• Your transmitter's power-supply filter capacitor was bad

Al Penney
VO1NO

Review Question 28

If you are told your station was heard on 21 375 kHz, but at the time you were operating on 7125 kHz, what is one reason this could happen?

• Your transmitter was radiating harmonic signals

• Your transmitter's power-supply filter choke was bad

• You were sending CW too fast

• Your transmitter's power-supply filter capacitor was bad

< Your transmitter was radiating harmonic signals >

The third harmonic of 7.125 MHz is 21.375 MHz.

Al Penney
VO1NO

Review Question 29

Your amateur radio transmitter appears to be creating interference to the television on channel 3 (60 - 66 MHz) when you are transmitting on the 15 metre band. Other channels are not affected. The most likely cause is:

- a bad ground at the transmitter
- front-end overload of the TV
- harmonic radiation from the transmitter
- no high-pass filter on the TV

Al Penney
VO1NO

Review Question 29

Your amateur radio transmitter appears to be creating interference to the television on channel 3 (60 - 66 MHz) when you are transmitting on the 15 metre band. Other channels are not affected. The most likely cause is:

• a bad ground at the transmitter

• front-end overload of the TV

• harmonic radiation from the transmitter

• no high-pass filter on the TV

< harmonic radiation from the transmitter >

The 15 m band is 21.00 – 21.450 MHz. Channel 3 is 60 – 66 MHz. For the sake of argument let us assume that you are transmitting CW on 21.050 MHz. If your transmitter is generating harmonics the third harmonic of 21.050 MHz is 63.150 MHz, right in the middle of Channel 3.

Al Penney
VO1NO

Review Question 30

One possible cause of TV interference by harmonics from an SSB transmitter is from “flat topping” - driving the final amplifier into non-linear operation. The most appropriate remedy for this is:

- reduce oscillator output
- reduce microphone gain
- retune transmitter output
- use another antenna

Al Penney
VO1NO

Review Question 30

One possible cause of TV interference by harmonics from an SSB transmitter is from “flat topping” - driving the final amplifier into non-linear operation. The most appropriate remedy for this is:

• reduce oscillator output

• reduce microphone gain

• retune transmitter output

• use another antenna

< reduce microphone gain >

Al Penney
VO1NO

Review Question 31

What type of filter might be connected to an amateur HF transmitter to cut down on harmonic radiation?

- A CW filter
- A low pass filter
- A key-click filter
- A high pass filter

Al Penney
VO1NO

Review Question 31

What type of filter might be connected to an amateur HF transmitter to cut down on harmonic radiation?

- A CW filter
- A low pass filter
- A key-click filter
- A high pass filter

< A low pass filter >

Al Penney
VO1NO

Review Question 32

What should be the impedance of a low pass filter as compared to the impedance of the transmission line into which it is inserted?

- About the same
- Substantially lower
- Twice the transmission line impedance
- Substantially higher

Al Penney
VO1NO

Review Question 32

What should be the impedance of a low pass filter as compared to the impedance of the transmission line into which it is inserted?

- About the same
- Substantially lower
- Twice the transmission line impedance
- Substantially higher

<About the same>

Al Penney
VO1NO

Review Question 33

To reduce harmonic output from a high frequency transmitter, you would put a in the transmission line as close to the transmitter as possible.

- high pass filter
- band reject filter
- wave trap
- low pass filter

Al Penney
VO1NO

Review Question 33

To reduce harmonic output from a high frequency transmitter, you would put a in the transmission line as close to the transmitter as possible.

• high pass filter

• band reject filter

• wave trap

• low pass filter

< low pass filter >

Al Penney
VO1NO

Review Question 34

To reduce energy from an HF transmitter getting into a television set, you would place a ___ as close to the TV as possible.

- wave trap
- band reject filter
- high pass filter
- low pass filter

Al Penney
VO1NO

Review Question 34

To reduce energy from an HF transmitter getting into a television set, you would place a ___ as close to the TV as possible.

• wave trap

• band reject filter

• high pass filter

• low pass filter

< high pass filter >

Al Penney
VO1NO

Review Question 35

A band pass filter will:

- allow only certain frequencies through
- attenuate high frequencies but not low
- pass frequencies each side of a band
- stop frequencies in a certain band

Al Penney
VO1NO

Review Question 35

A band pass filter will:

- allow only certain frequencies through
- attenuate high frequencies but not low
- pass frequencies each side of a band
- stop frequencies in a certain band

< allow only certain frequencies through >

Al Penney
VO1NO

Review Question 36

A band reject filter will:

- pass frequencies each side of a band
- allow only two frequencies through
- pass frequencies below 100 MHz
- stop frequencies each side of a band

Al Penney
VO1NO

Review Question 36

A band reject filter will:

• pass frequencies each side of a band

• allow only two frequencies through

• pass frequencies below 100 MHz

• stop frequencies each side of a band

< pass frequencies each side of a band >

Al Penney
VO1NO

Review Question 37

A low pass filter suitable for a high frequency transmitter would:

- attenuate frequencies above 30 MHz
- pass audio frequencies above 3 kHz
- attenuate frequencies below 30 MHz
- pass audio frequencies below 3 kHz

Al Penney
VO1NO

Review Question 37

A low pass filter suitable for a high frequency transmitter would:

- attenuate frequencies above 30 MHz
- pass audio frequencies above 3 kHz
- attenuate frequencies below 30 MHz
- pass audio frequencies below 3 kHz

< attenuate frequencies above 30 MHz >

Remember that the HF band is 3–30 MHz, so you want to attenuate frequencies above 30 MHz and not below 30 MHz. Audio frequencies in this question are a red herring.

Al Penney
VO1NO


Questions?
Al Penney
VO1NO