Joe Carr's Radio Tech-Notes

Dealing With AM Broadcast Band Interference to Your Receiver

Joseph J. Carr

Universal Radio Research
6830 Americana Parkway
Reynoldsburg, Ohio 43068

Dealing With AM Broadcast Band Interference to Your Receiver

Joseph J. Carr

If you live anywhere near an AM broadcast band (BCB) station, then you might have serious reception problems, even with a high quality receiver. Although one of the things you get when you pay the premium price for a high quality receiver is superior overload protection, the signal from a local AM BCB station might overwhelm its defenses.

In the USA we use the 530-1700 Khz medium wave AM BCB. Most stations operate with 1,000 to 10,000 watts of RF output power (although a few 250 to 500 watt local fizzlers also exist). A few stations are designated "clear channel" stations, and operate with 50,000 watts, 24-hours a day. These stations (e.g. WSM Nashville, 650 Khz) are on frequencies that are not assigned to other stations for a distance of, I believe, 1300 miles radius. If you live within a few hundred yards of an AM BCB station, then it's possible to see more than one volt of RF appearing at your receiver antenna terminals (a laboratory measured 4 volts in one case!). Given that your receiver likes to see signals in the dozens of microvolts level, then you can understand the problem.

The Problem

So what is the problem? Your receiver, no matter what frequency it receives, is designed to accept only a certain maximum amount of radio frequency energy in the front-end. If more energy is present, then one or more of several *overload conditions* results. The overload could result from a desired station is too strong. In other cases, there are simply too many signals within the passband for the receiver front-end to accommodate. In still other cases, a strong out-of-band signal is present. Figure 1 shows several conditions that your receiver might have to survive. Several different receiver problems result from the various types of overload, all of which are species *intermodulation* and/or *crossmodulation*.

If you tune across the shortwave bands, especially those below 10 or 12 Mhz, and note an AM BCB signal that seems like it is hundreds of kilohertz wide, then you are witnessing blanketing. If drives the mixer or RF amplifier of the receiver clean out of its mind, producing a huge number of spurious signals, and apparently a very wide bandwidth.

Your receiver can only accommodate a certain amount of RF energy in its front-end circuits. This level is expressed in the dynamic range specification of the receiver, and is hinted by the third-order intercept point (TOIP) and -1 dB compression point specifications. The strong out-of-band signal takes up so much of the receiver's dynamic range "head room" that only a small amount of capacity remains for the desired signal. The signal level of the desired signal is thereby reduced to a smaller level. In some cases, the overload is so severe that the desired signal becomes inaudible. If you can filter out or otherwise attenuate the strong out-of-band signal , then the head room is restored, and the receiver has plenty of capacity to accommodate both signals.

One thing that's important today is what happens when signals are received that are much stronger than the input signal that produces the flattening of the response in the output-vs-input curve. One unfortunate factor is the generation of harmonics that were not present in the original signal. The harmonics are integer multiples of the input signal frequency, so will appear at higher points on the frequency dial. The harmonics may fall within the passband of your receiver, and are seen as valid signals even though they were generated in the receiver itself!

The strong intermodulation products are created when two of these signals heterodyne together. The heterodyne ("mixing") action occurs because the receiver front-end is non-linear at this point. The frequencies produced by just two input frequencies (F1 and F2) are described by $mF1 \pm nF2$, where m and n are integers. As you can see, depending on how many frequencies are present and how strong they are, a huge number of spurious signals can be generated by the receiver front-end.

So, what about IF selectivity? You have an IF filter of 270 Hz to 8 Khz (depending on model and mode), so why doesn't it reject the dirty smelly bad-guy signals? The problem is that the damage occurs in the front-end section of the receiver, before the signals encounter the IF selectivity filters.

The problem that causes all of these problems is an overdriven RF amplifier, mixer or both. The only really effective way to deal with these problems is to reduce the level of the offending signals. In this paper we will investigate the use of front-end attenuators, high-pass filtering and single-frequency wavetraps.

The Attenuator Solution

Some modern receivers are equipped with one or more switchable attenuators in the front-end. Some receivers also include an RF gain control that sometimes operates in the same manner. Some receiver operators use external in-line single-range or switchable attenuators for exactly the same purpose. The idea behind the attenuator is to reduce all of the signals to the front-end enough to drop the overall energy in the circuit to below the maximum level that can be accommodated without either overload or intermodulation occurring at significant levels. The attenuator reduces both desired and undesired signals, but the perceived ratio is altered when the receiver front-end is de-loaded to a point where desensitization occurs, or intermods and harmonics pop up.

The Antenna Solution

The antenna that you select can make some difference in AM BCB problems. Generally, a resonant HF antenna with its end nulls pointed toward the offending station will provide marginally better performance than a random length wire antenna (which are popular amongst SWLs).

Also, it is well known that vertical HF antennas are more susceptible to AM BCB because they respond better to the ground wave electrical field generated by the BCB station (DeMaw).

The Filter Solution

One of the best solutions is to filter out the offending signals before they hit the receiver front-end, while affecting the desired signals minimally. This task is not possible with the attenuator solution, which is an “equal opportunity” situation because it affects all signals equally. A signal that is outside the passband of a frequency selective filter: it is severely attenuated. It does not drop to zero, but the reduction can be quite profound in some designs.

Signals within the receiver’s passband are not unaffected by the filter. The loss for in-band signals is, however, considerably less than for out-of-band signals. This loss is called <u>insertion loss</u>, and is usually quite small (1 or 2 dB) compared to the loss for out-of-band signals (lots of dB).

Several different types of filter are used in reducing interference. A *high-pass filter* passes all signals *above* a specified cut-off frequency (F_c). The *low-pass filter* passes all signals *below* the cut-off frequency. This filter is similar to the type of filter that hams using HF transmitters place between the transmitter and antenna to prevent harmonic radiation from interfering with television operation.

A bandpass filter passes signals between a lower cut-off frequency (F_L) and an upper cut-off frequency (F_H). A *stop-band* filter is just the opposite of a bandpass filter: it stops signals on frequencies between F_L and F_H, while passing all others. A *notch* filter, also called a wave trap, will stop a particular frequency (F_o), but not a wide band of frequencies as does the stopband filter. In all cases, these filters stop the frequencies in the designated band, while passing all others. More or less.

The positioning of the filter in your antenna system is shown in Fig. 1 below. The ideal location is as close as possible to the antenna input connector. The best practice, if you have the space at your operating position, is to use a double-male coaxial connector to connect filter output connector to the antenna connector on the receiver.

A short piece of coaxial cable can connect the two terminals if this approach is not suitable in your case. Be sure to ground both the ground terminal on the receiver and the ground terminal of the filter (if one is provided). Otherwise, depend on the coaxial connectors’ outer shell making the ground connection.

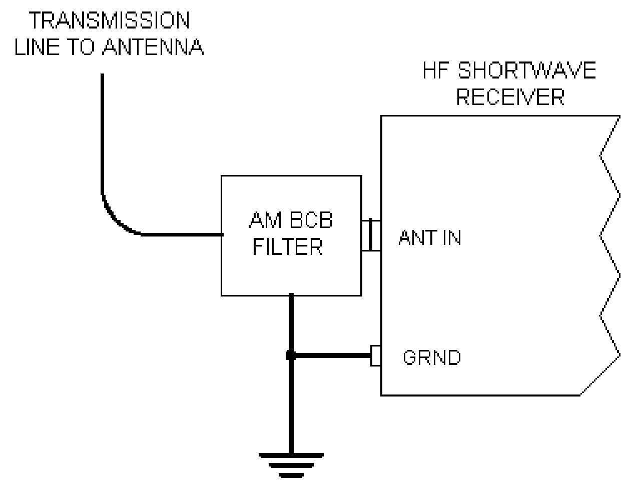


FIG. 1

Different Forms of Filter

Wave traps

A wave trap is a tuned circuit that causes a specific frequency to be rejected. Two forms are used: *series tuned* (Fig. 2A) and *parallel tuned* (Fig. 2B).

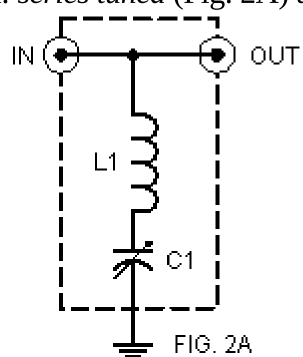


FIG. 2A

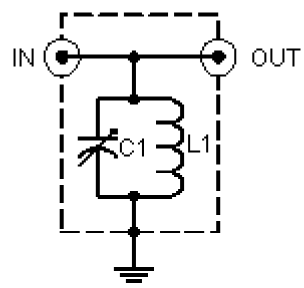


FIG. 2B

The series tuned version of the wavetrap is placed across the signal line (as in Fig. 2A), and works because it produces a very low impedance at its resonant frequency and a high impedance at frequencies removed from resonance. As a result, the interfering signal will see a resonant series-tuned wave trap as a short circuit, while other frequencies do not see it at all. The parallel resonant form is placed in series with the antenna line (as in Fig. 2B). It provides a high impedance to its resonant frequency, so will block the offending signal before it reaches the receiver. It provides a low impedance to frequencies removed from resonance.

The wave traps are useful in situations where a single station is causing a problem, and you don't want to eliminate nearby stations. For example, if you live close to an MW AM BCB signal and don't want to interrupt reception of other MW AM BCB signals or LW

AM BCB signals. Even AM BCB DXers often have wavetraps tuned to the frequency of a nearby station in order to either increase the available dynamic range or eliminate other problems.

The values of components shown in Figs. 2A and 2B are suitable for the MW AM BCB, but can be scaled to the LW BCB if desired. A good starting point is 365 pF for the variable capacitor, and 200 µH or 220 µH for the inductor. Both components should be variable in order to make tuning easier. However, if one component is fixed, the filter will do its job just as well.

If there are two stations causing significant interference, then two wave traps will have to be provided, separated by a short piece of coaxial cable. In that case, use a parallel tuned wave trap for one frequency, and a series tuned wave trap for the other. Otherwise, interaction between the wave traps will cause problems.

High-Pass Filters. One very significant solution is to use a high-pass filter with a cut-off frequency between 1700 and 3000 Khz. It will pass the shortwave frequencies, and severely attenuate AM BCB signals in both MW and LW bands, causing the desired improvement in performance. Figure 3 shows a design used for many decades. It is easily built because the capacitor values are 0.001 µF and 0.002 µF (which some people make by parallelling two 0.001 µF capacitors).

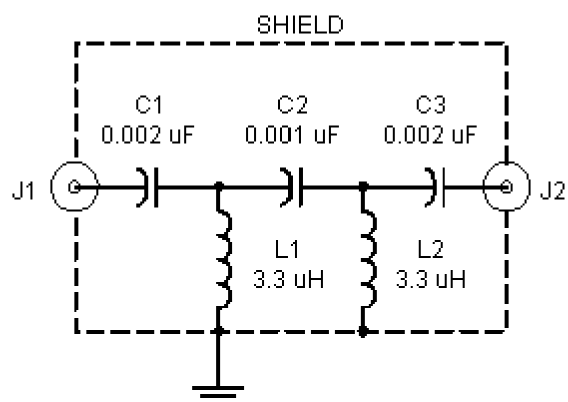
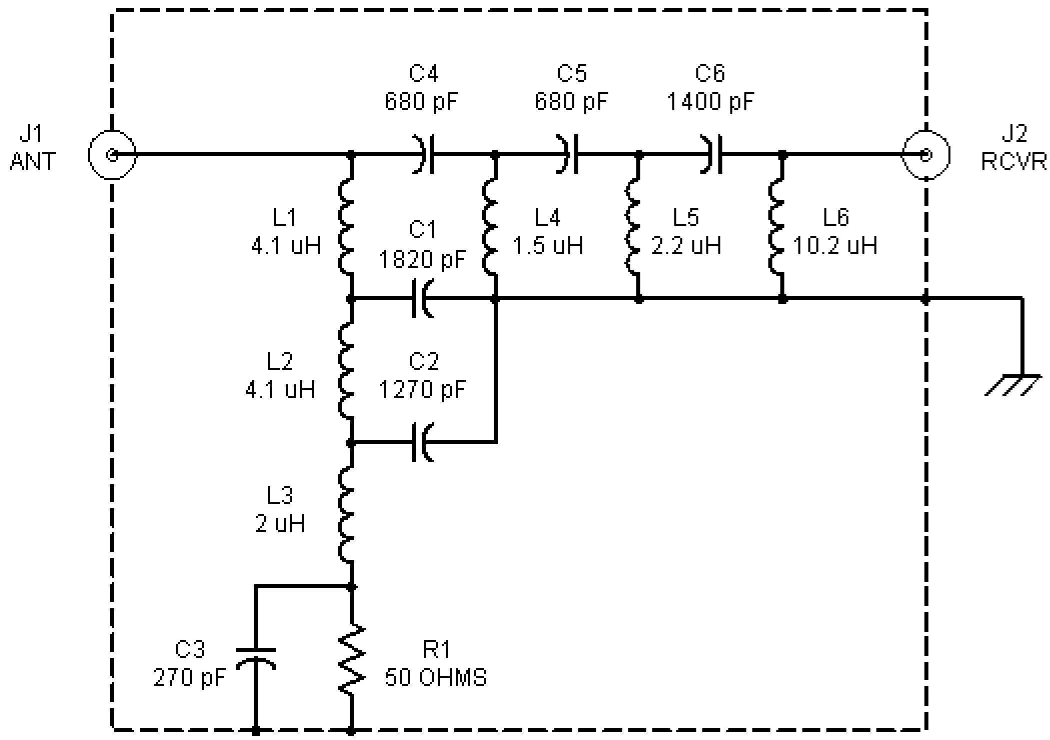


FIG. 3

The inductors are both 3.3 µH, so can be made with toroidal cores. If the T-50-2 RED cores are used (A_L = 49), then 26 turns of small diameter enameled wire will suffice. Or if the T-50-15 RED/WHITE cores are used (A_L = 135), then 15 turns are used. The circuit of Fig. 3 produces pretty decent results for low effort. A number of readers contacted me with success stories when this circuit was published once before, a result that gives me pleasure. But there is a better way....

Absorptive Filters. The absorptive filter (Orr 1996 and Weinreich/Carroll 1968) solves a problem with the straight high-pass filter method, and produces generally better results at the cost of more complexity. This filter (Fig. 4) consists of a high-pass filter (C4-

C6/L4-L6) between the antenna input (J1) and the receiver output (J2). It passes signals above 3 Mhz and rejects those below that cut-off frequency. It also has a low-pass filter (C1-C3/L1-L3) that passes signals below 3 Mhz. What is notable about this filter, and from which it takes its name, is the fact that the low-pass filter is terminated in a 50 ohm dummy load. This arrangement works a little better than the straight high-pass filter method because it absorbs energy from the rejected band, and reduces (although does not eliminate) the effects of improper filter termination.



Some of the capacitor values are non-standard, but can be made using standard disk ceramic or mica capacitors using combinations in Table 1:

Table 1

C1: 1,820 pF	Use 1000 pF (0.001 µF or 1 nF) in parallel with 820 pF
C2: 1,270 pF	Use 1000 pF and 270 pF in parallel
C6: 1,400 pF	Use 1000 pF, 180 pF and 220 pF in parallel.

The other capacitors are standard values.

The coils are a bit more difficult to obtain. Although it is possible to use slug-tuned coils obtained from commercial sources (e.g. Toko), or homebrewed, this is not the preferred practice. Adjusting this type of filter without a sweep generator might prove daunting due to interactions between the sections. A better approach is to use toroid core homebrew inductors. The toroidal cores reduce interaction between the coil's magnetic fields, so simplifies construction. Possible alternatives are shown below in Table 2:

Table 2

Coil	**Value**	**Core**	**A_L Value**	**Turns**
L1	4.1 µH	T-50-15 RED/WHITE	135	17
L2	4.1 µH	T-50-15 RED/WHITE	135	17
L3	2 µH	T-50-15 RED/WHITE	135	12
L4	1.5 µH	T-50-2 RED	49	18
		T-50-6 YEL	40	20
L5	2.2 µH	T-50-2 RED	49	21
		T-50-6 YEL	40	24
L6	10.2 µH	T-50-2 RED	49	46
		T-50-6 YEL	40	51

For all coils use wire size to #24 to #30 AWG enamel insulation.

The dummy load used at the output of the low-pass filter (R1 in Fig. 4) can be made using a 51 ohm carbon or metal film resistor, or two 100 ohm resistors in parallel. In a pinch a 47 ohm resistor could also be used, but is not preferred. In any event, use only noninductive resistors such as carbon composition or metal film 1/4 to 2-watt resistors.

If you would like to experiment with absorptive filters at other cut-off frequencies than 3 Mhz, then use the reactance values in Table 3 to calculate component values:

Table 3

Component	**X (X_L or X_C)**
L1	28.8 Ω
L2	78.4 Ω
L3	38 Ω
L4	28.8 Ω
L5	42 Ω
L6	193 Ω
C1	28.8 Ω
C2	42 Ω
C3	193 Ω
C4	78.4 Ω
C5	78.4 Ω
C6	38 Ω

The exact component values can be found from variations on the standard inductive and capacitive reactance equations:

Microhenrys

and,

picofarads

These component values are bound to be non-standard but can be made either using coil forms (for inductors) or series-parallel combinations of standard value capacitors.

Shielding

Shielding is a non-negotiable requirement of filters used for the QRM reduction task. Otherwise, signal will enter the filter at its output and will not be attenuated. Use an aluminum shield box of the sort that has at least 5-6 mm of overlap of the flange between upper and lower portions. I used a tinned steel RF box for this purpose when building the prototype for this filter.

Expected Results

If the correct components are selected, and good layout practice is followed (which means separating input and output ends), then the absorptive filter offers stopband attenuation of -20 dB at one octave above F_c, -40+ dB at two octaves and -60 dB at three octaves. For a 3 Mhz signal, one octave is 6 Mhz, two octaves are 12 Mhz and three octaves are 24 Mhz. My results were slightly less than these figures because some of my components were ill-matched (e.g. slug-tuned commercial inductors were used rather than toroid core coil).

A design suitable for the US television bands is provided by Weinreich/Carroll (1968). The same source also shows a number of other absorptive filter designs for those hams and SWLs who would like to experiment. SWLs who consult that source should remember that the roles of the receiver and dummy load must be reversed for the filter to be useful.

Conclusion

The problem of MW/LW AM BCB interference to HF shortwave receivers can be daunting, indeed, because of the high power level of signals encountered. Even good quality receivers will balk at handling those powerhouse sluggers. The use of either wave traps, high pass or absorptive filters will do the trick for all but the most severe cases. I've even seen it work inside the antenna/transmitter room of an AM station operating with 5,000 watts (the on-duty engineer was a ham, and was goofing off!).

References

DeMaw, Doug, W1CER (1967). "Rejecting Interference From Broadcast Stations." QST, December 1967, pp. 35-38.

Orr, Bill W6SAI (1996). HF Antenna Handbook. Hicksville, NY: CQ Communications, Inc. p.6-19.

Weinreich, Richard K6UVU and R.W. Carroll (1968). "Absorptive Filters For TV Harmonics." QST, November 1968, pp. 20-25.