A Line-Synchronous Noise Blanker

About Line Noise:

One of the banes of the VLF/LF/MF listener is powerline noise. Down at these frequencies (several MHz and below) the energies of various electronic switching devices (such as light dimmers, motor controllers, fluorescent lights, etc.) are very strong. There are several reasons for this: Harmonics tend to decrease in energy with increasing frequency, and at these low frequencies, their energy hasn't dropped off by much. Another reason is that the filters built into devices such as light dimmers just aren't effective below several hundred kilohertz. Finally, these devices are typically connected directly to the house wiring and are therefore conducted into equipment and radiated on inside wiring and powerlines.

Efforts to rid yourself of this type of noise may be hard-fought battles, particularly at LF and below: A filter that works effectively at LF frequencies is likely to be too large to fit within the fixture or enclosure of the device for which it is intended.

There are several other ways to minimize the impact of powerline-related noise on your listening:

- Listen only during power failures. (Rare occurrences for most of us...)
- Listen well away from powerlines. (Not convenient at most of our homes.)
- Careful location of the receive antenna. Locating the antenna away from noise-generating devices and powerlines will minimize reception of such noise.
- The use of a shielded loop or other H-field antenna. These types of antenna are less-responsive to near-field E-field noise, often a major component of received noise. This type of antenna can also be rotated to null the noise source.

Assuming that you have tried all of these but you need ***more*** help, then a noise blanker may be for you.

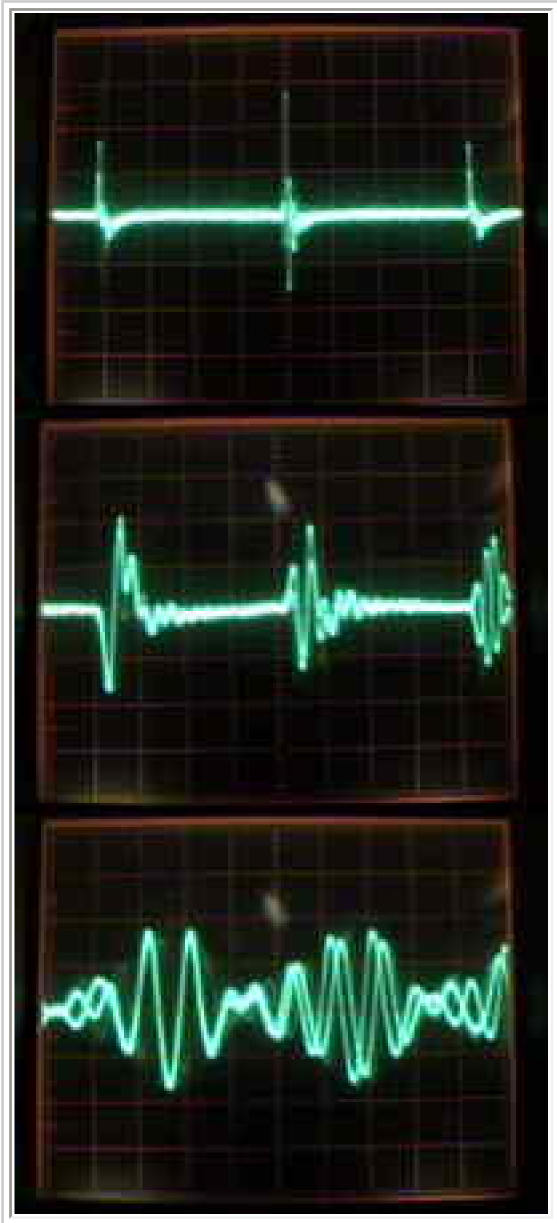
Most of today's radios contain something referred to as a "noise blanker." Those who have used these noise blankers also know that most of them have only limited effect on powerline-type noise. Many of them will also cause large amounts of intermodulation distortion in their operation, obscuring weaker signals. A few noise blankers (such as the one in the Drake TR-7/R-7 or R-4 lines) do work well, but these blankers (as well as others) are affected by nearby strong signals. Furthermore, they don't usually work on but the first "layer" of line noise (more on this later.)

A Brief Analysis of Line Noise:

Line noise typically occurs on both sides of the power line sinusoid. That is, it produces pulses at ***twice*** the line frequency (we'll assume throughout this page that we are talking about a U.S. power system) at 120 Hz. Even so, this noise often has strong 60 Hz components as well. The result of this is that powerline-related noise produces energy every 60 Hz across the spectrum. To further complicate matters, AC power is distributed by the utility in three phases, each being 120 degrees from the other phase: This can seem to "multiply" the number of noise pulses that occur during each cycle of the powerline's waveform.

The noise is produced by the abrupt switching of some device (i.e. a triac in a light dimmer.) This fast switching produces noise pulses extremely rich in harmonics. The timing of this pulse with respect to the "beginning" of the sinusoid (let's say that this is where it crosses zero on the positive-going portion) can vary, depending upon when the offending device triggers. This can also be offset in timing if, say, the device is operated on a different phase of a three-phase power system, for example. This fast switching produces a pulse that is very narrow (a few tens of microseconds or less by the time it reaches your antenna.)

What about filters? While it is true that with a narrower filter, less noise energy will be intercepted, but there is another problem: Narrower filters tend to ***stretch*** noise pulses. The three images to the right demonstrate this. These images are from a line-triggered oscilloscope connected to the audio output of a Drake TR-7. Three filter settings are used (top to bottom) with the first one being a 12 KHz filter (only the first IF filters are used) followed by a 2.2 KHz SSB filter and a 300 Hz CW filter.



From top to bottom: Dimmer noise pulses in a 12 KHz, 2.2 KHz, and a 300 Hz filter. Note the widening of the pulses with progressively narrower filters. (Division are 2 ms)

With the 12 KHz filter (the top image) the vast majority of the noise pulse energy occurs within 1/8 of a division (about 250 microseconds) with a bit of ringing extending through 1 millisecond. Contrast this with the middle image depicting the same pulse, but through a 2.4 KHz SSB filter. Notice that the pulses now drag out to longer than 1 millisecond, about 4 or 5 times longer than before. The bottom image shows the same pulse through a 300 Hz CW filter: The pulses are actually beginning to run together.

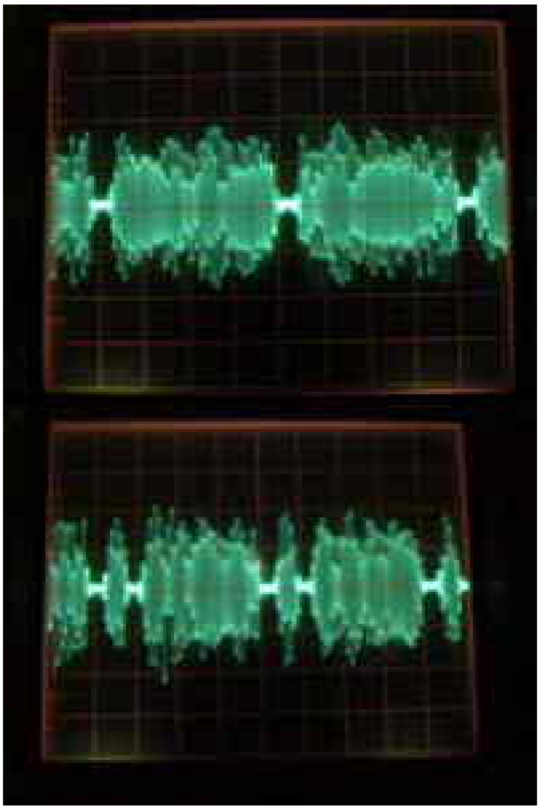
It is true that most receiver noise blankers are placed earlier in the IF of a receiver - ***before*** the main bandwidth-determining filters, but even these receivers do have (wider) bandpass filter that tend to stretch out the pulses somewhat.

All is not lost: With powerline noise, we have an advantage over random noise in that we know very precisely its repetition rate - 60 or 120 Hz (in the U.S. and a few other countries, at least.) Furthermore, this noise source is most likely powered from the same power grid as ***your*** equipment (even if it isn't on the same phase as you) and thus you have a ready-made reference for the noise-pulse frequency. What is ***not*** known is the precise position and width of the offending pulse.

(By the way, the noise blanker described reduced the above "light dimmer noise" by well over 35 db.)

Deleting the offending noise pulse(s)...

As can be observed above, simply muting the pulses at audio is not a very good solution due to the stretching of the pulses by the receiver's filters. If this fact weren't the major concern, there is the problem of the receiver's AGC action attenuating the ***desired*** signal: The noise will set the AGC to levels based on the strongest signal being receive (even noise) - but if the desired signal is, say, 15 db below the noise peaks, the AGC will bury that signal 15 db in the audio... among the stretched noise pulses...



The effects of the blanker on a received signal. The top image shows the "holes" punched in the received signal with one blanking channel, the bottom image shows two active blanking channels. The blanking widths are exaggerated for clarity.

What we need to do is blank the RF ***during*** the noise pulse ***before*** it gets to any of the receiver's filters: Since the noise pulse itself is (usually) of very short duration, we don't need to blank it for very long. The most obvious place to do this is at the antenna connection. This may be done several ways. The blanking gate described here uses PIN diodes in an attenuator arrangement. This attenuator provides attenuation that is related to the current applied to its diodes and is fairly "linear" even when only partial attenuation is occurring. This is important if you want to minimize the amount of intermodulation that the noise blanker will cause. The use of MPN3404 PIN diodes is intentional here. This circuit ***will*** work with ordinary 1N914/1N4148-type diodes, but expect performance to be worse.

Most important to intermodulation reduction is careful control of the ***slew rate*** of the blanking pulse. If one were to simply employ a switch that turned the antenna on and off, the switch itself would cause ***significant*** harmonics and the blanker itself would cause what sounds like line noise. If one (relatively) slowly turns the attenuation on and off during the blanking, you can greatly reduce the possibility of intermodulation and reduce the bandwidth and intensity of the "blanking sidebands" that are necessarily created during blanking (we are amplitude modulating our received signals with the blanking pulse, remember...)

As it turns out, while there is typically one major noise pulse causing most of the buzzing, but there may be several other noise pulses occurring during different times. That is, if you blank just one set of the offending pulses, there may be another set that you are now able to hear that also obscures the desired signal. You may wish to have the ability to set up individual blanking pulses for the various "layers" of noise.

Description of the circuit:

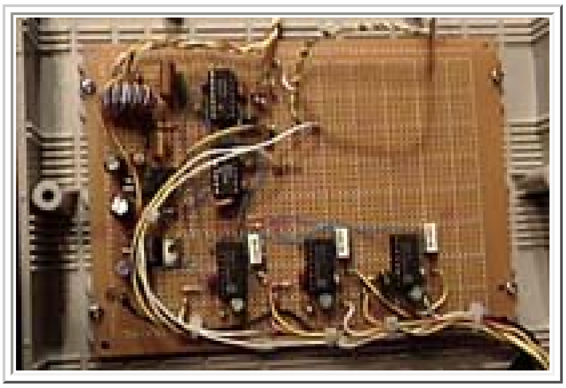
What we need is a device that will produce a blanking pulse that has two adjustable parameters: Position and width. The position is relative (in this case) to the zero crossings of the 60 Hz line frequency (which occur at a rate of 120 Hz) and the width is, well, width...

The schematic of the unit described may be found here. *(Schematic updated/corrected on 7 December, 2001)*

Schematic versions:

- Version 1.00 - Original version of schematic
- Version 1.01 - Added pin numbers to ICs, fixed minor errors - 4/2000
- Version 1.02 - Corrected pin numbers on U1B (e.g. pins 9 & 11 were swapped) - 1/2001
- Version 1.03 - Added designation of diode on blanking generator output, made schematic file smaller - 11/2001
- Version 1.04 - Added some waveforms and nomenclature to switches - 12/2001

When printing the schematic, select LANDSCAPE mode so it will fit on the page.



A view of the proto board containing the pulse and blanking generators.
(Click on the picture for a larger view)

The blanker is powered by a 18 volt AC power cube. This power is filtered and isolated (at RF frequencies) with a bifilar-wound inductor removed from a defunct computer switching power supply. This inductor has several millihenries of self-inductance and it prevents noise that *might* be conducted from the power cube (from the power line) into the receiver itself.

This power is then half-wave rectified and filtered and applied first to a 7818 regulator for a stable 18 volt DC supply (for the blanking drivers and for powering the receive antenna on the coaxial cable) and then filtered and regulated to 5 volts for the timing logic. The capacitor across the diode and series resistor are used to suppress any "hash" that might be produced by the diode rectifier.

A portion of the pre-rectified AC is extracted, AC coupled, and applied to U2C which is wired as a comparator. This produces a 60 Hz 18 volt square wave. This square wave is resistively divided down to approximately 5 volts and applied to U3B, a 74HC86. This buffers the 60 Hz square wave and applies it to U3A which is wired as an edge-detector. The resistor/capacitor combination on its input cause this section to produce a narrow pulse on each transition of the 60 Hz square wave, thus producing a 120 Hz pulse train. This train is buffered by U3D and is made available for the blanking-pulse generators. The remaining section (U3C) is simply tied to U3D so that it's input isn't floating and is therefore unused. (Yes, I should have tied it to to either the ground or the 5 volt supply, but I was lazy...)

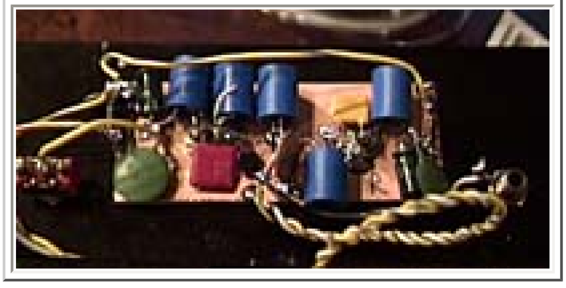
The 120 Hz pulse train is applied to U1B, a 74HC123, a dual one-shot timer. U1B is the "position" timer and has a period that is adjustable from a few microseconds to the entire duration of the 120 Hz pulse repetition interval to allow blanking to occur at any point in the period of the pulse train. The output of this is first section is sent to U1A.

Since U1A is edge-triggered, it responds ***only*** to the ***rising*** edge of the pulse from U1B - the end of the timing period. The section of U1A operates exactly like the U1B section, except that its timing range is restricted to approximately one-third of the interval of the 120 Hz pulse train. This section functions as the "width" generator for the blanking pulse.

The finished blanking pulse appears on pin 4 of U1A. It is at this point that this blanker generator may be "diode-ORed" with the outputs of other pulse generators. If it is desired that more than one blanking pulse is needed (at least two are recommended) then the next section would be connected at this point. For enabling/disabling a blanking generator, a switch is placed on pin 3 of U1A to enable/disable the timer. For a single section blanker (or for the first of several blanking channels) this may be simply tied to +5V.

U2D, an Op-Amp section, is used as a comparator. It takes the diode-ORed input from the pulse generator(s) (using a 10k pullup resistor) and generates inverted 18 volt blanking pulse. This pulse is then shaped by U2A which is wired as a 3rd order lowpass filter. A 100k resistor limits the maximum output to prevent clipping of the amplifier at the 18 volt rail and thus prevents distortion (and the ensuing harmonics) from the blanking pulse. A switchable 0.018 microfarad capacitor allows selection of a lower slew rate to allow the blanker to be used at lower LF frequencies (more on this later.)

The filtered output of the blanking generator is applied to the PIN diodes through a resistor (for current limiting) and across a capacitor and through an inductor (for RF decoupling.) When the voltage is high, current flows through the two PIN diodes, turning them on. When the voltage is off, the diodes do not conduct and high isolation is obtained.



The PIN diode attenuator section of

Surrounding the PIN diode network are other inductors and capacitors that allow for power passing and insertion to allow active antennas to be powered by the blanker's power supply and/or the receiver.

the noise blanker. (Note that there are 2 extra coils shown - these were originally used in the prototype, but bypassed - but not removed - in the "final" version.)
(Click on the picture for a larger view)

Construction notes:

The prototype unit (shown in the pictures) is a three-channel synchronous noise blanker. (The schematic of the noise blanker is here.) Although two channels usually suffice, there are (rare) instances where all three are required.,

Front panel view of the Synchronous noise blanker.
(Click on the picture for a larger view)

The front panel shows six potentiometers: One for **position**, and another for **width** for each of the three channels. Channels 2 and 3 (the middle and the one on the right, respectively) have switches mounted the rear of their **width** control pots. These switches are used to disable their respective channels. They are placed on the width control so that the channel may be disabled without disturbing the pulse position settings. Each of these pots is wired such that counterclockwise rotation corresponds to the shorter timing interval for the associated timer (i.e. "earlier" blanking pulse for the **position** control, or "narrower" blanking pulse for the **width** control.)

Rear view of the front panel showing the wiring of the potentiometers.
(Click on the picture for a larger view)

The PIN diode attenuator is constructed on a piece of circuit board material and is mounted using the antenna connectors (RCA connectors, in this case.) This provides for a good "RF" ground, mechanical rigidity, and minimizes extraneous RF pickup or radiation. 1.5 and 2.2 microfarad ceramic capacitors are used for DC decoupling and these values are sufficiently large enough to allow for minimal attenuation at VLF frequencies. If response at such low frequencies (below 10 KHz) is not needed, lower-value capacitors may be used. If such large-value ceramic capacitors are not available, electrolytic capacitors may be used (observe polarity!) It is recommended that electrolytic capacitors (if used) are paralleled with some 0.1 uf ceramic capacitors to minimize losses that electrolytics often exhibit at higher frequencies.

With my receiver (a Drake TR-7) I have an "LF Interface box" that puts power on the LF antenna input connector to power an active antenna. Diodes are employed to steer power from the receiver to the antenna and from the noise blanker. A switch is used to enable/disable this power - useful if using a passive antenna.

It is recommended that the bodies of the potentiometers and switches be grounded to reduce "hand effects" and to protect the CMOS circuitry from static discharges.   It is also strongly recommended that the timing capacitors on U1A and U1B (the 0.068 and 0.022 uf units) be (relatively) temperature-stable devices such as mylar or polyester: Ceramic devices of this value are usually ***not*** stable with temperature and you may be plagued with temperature-related drift of the position and width adjustments.

A view of the rear panel of the synchronous noise blanker. A banana jack (left) is for monitoring the blanking pulse with an oscilloscope.
(Click on the picture for a larger view)

Operation of the unit:

Most of the time, operation of just ***one*** blanking channel will eliminate *most* of the noise. Even if two blanking channels *are* ultimately required, you start out with just one. The noise blanker is set up thusly:

1. Turn off the receiver's noise blanker. Since the idea is to null the noise, you don't want the radio's blanker to make it harder to hear the noise while you are doing your adjustments.
2. Make sure that only **one** of the synchronous noise blanker's channels is on.
3. Set the receiver's bandwidth to a fairly wide setting (usually an SSB or AM filter.) This will allow the noise to be heard more clearly as you null it out.
4. Set the receiver's AGC to SLOW, or turn it OFF (adjusting the RF gain to set the signal to a comfortable level.) This will allow easier nulling of the noise.
5. Set the **width** control to to about mid-rotation.
6. Slowly, carefully rotate the **position** control. A definite decrease in the powerline noise (the "buzz") should be noted at some position - unless you just *happen* to have two noise sources of different timing and similar strength.
7. Adjust the **width** control to narrow the pulse slightly. Readjust the **position** control to re-null the noise. Repeat the previous steps. If you adjust the **width** control too narrow, a deep null cannot be obtained. Adjusting the **width** control too wide can result in needless incidental AM modulation of desired signals (more on this later...)
8. At this point it may become obvious that there is more than one noise pulse and a second (or third!) blanker channel may be activated. It is adjusted in the same way as the first. It may be advantageous to "touch up" the first channel to achieve maximum noise reduction.
9. If you are trying to listen to VLF signals (i.e. those below 30 KHz) it is possible that the switching of the PIN diodes themselves may cause some audible harmonics at the switching rate. At (and below) these frequencies, one would set the **slew rate** switch to the **slow** position. Note that changing the switch setting will usually necessitate readjustment of all **width** and **position** controls on all enabled channels.
10. The AGC, filter, and noise blanker settings may be returned to their normal positions.

After using the blanker, you'll get the "feel" of how it operates and you should be able to quickly set up the **position** and **width** controls for best noise elimination.

Operational notes and comments:

There are a few comments about a synchronous noise blanker, what the blanker ***will*** and ***will not*** do:

- A noise blanker such as this will work ***only*** on impulse-type noise that is created by a line-powered device. It will do ***absolutely nothing*** for atmospheric noise or "white" (hissy) type noise.
- When the blanking pulse is active, the receiver is muted briefly. This has approximately the same effect as amplitude-modulating the received signal with the blanking pulses. Because of this, even a CW note will acquire a slight "buzz" and some sidebands will be generated. The intensity and "bandwidth" of these added sidebands (i.e. the added "buzz") will vary with the setting of the **width** control and the slew rate of the blanking pulse, as well as the number of blanking channels that are active. Usually, the resultant buzzing is *far* less offensive than the noise you are blanking.
- It may be useful to use the radio's built-in noise blanker. These are often effective against the random impulse noise pulses (such as lightning, etc.) and can prevent these pulses from causing AGC action that might momentarily "deafen" the receiver, causing you to miss a portion of an ID, for example.
- There is an "enable-disable" switch shown on the noise blanker. This does ***not*** disable the blanking generator, but rather it turns the PIN diodes fully on (i.e. set to minimum attenuation.) It was convenient to disable the blanker in this manner, but one could do it by disabling the blanking generators as well (making sure that they are disabled in the "on" state, effectively muting the receiver.)
- Most active antennas get their power through the coaxial cable. The "power passthrough" switch enables/disables this supply. 18 volts is applied for the active antenna's power, but you should build this such that it suits the requirements for your active antenna.
- If the the blanker is used on a wire antenna it is possible that very strong signals (such as local AM stations) can cause the PIN diodes to produce intermodulation. This can be prevented by using an antenna matching network (which can often provide an effective bandpass response) a bandpass filter, or even a lowpass filter. This is not usually a problem on active antennas as they typically have sufficient rolloff characteristics to prevent such overload.
- The effectiveness of a synchronous noise blanker (and more traditional types) is somewhat less at higher frequencies. This is because the noise tends to become "hissy" due to some "smearing" of the original noise source - probably due to incidental phase modulation. For this reason, a blanker such as this is most useful below a few megahertz.
- Even though these descriptions are based on using the device on a U.S. (60 Hz) powerline system, there is no reason why it wouldn't work equally well on a 50 Hz power system. The capacitor and/or resistor values on the pulse and width timers may have to be adjusted slightly to accommodate the longer periods associated with 50 Hz power.
- You may notice that the "null" seems to change with receive frequency. For example, I've noticed that the settings for the best null at, say, 20 KHz are different for the best null at 200 KHz. ***Why?*** It could be that different noise sources appear at the different frequencies. It could also be that the group delay in the active antenna changes with frequency, causing the apparent position to change accordingly. At higher frequencies it is a different device that is being heard? There are many possibilities that come to mind.
- There is an inherent 4-6 db loss in the noise blanker when it is ***not*** blanking. This is due to the

loading of the RF lines due from the 470 ohm resistors used, as well as other miscellaneous losses. Usually, this isn't too much of a problem as the loss of 6 db or so isn't usually enough to put the normal atmospheric noise below the receiver's threshold - even on a quiet night. If you are using a passive antenna or if the receiver you use is very "deaf" at these frequencies (many of them are) then this extra attenuation may adversely affect your receive ability. In other words: If you always get an "S-Meter" reading on noise with the noise blanker in line, you aren't missing any signals...

- A minor improvement could be made to the performance of this blanker at extremely ***low*** frequencies (i.e. <10 Khz.) At the moment, the slew rate of the blanking pulse is adjustable simply by placing more capacitance on the line. To do it properly, one would change the characteristics of the entire shaping filter to provide a more sinusoidal waveform at the lower rate rather than simply tack a capacitor across the line. This would probably mean building a second filter with the lower frequency response, thereby minimizing the harmonic energies present in the blanking pulse that might appear in the receiver passband. (*Did that make sense?)*

Other pages at this site:

The CT MedFER Beacon page - This page describes a PSK31 MedFER beacon.

The CT LowFER Beacon Archive - Some pictures/info about the "CT" LowFER beacon of the late 1980's. (Includes QSLs and sounds from some other beacons of the time.)

"QRSS and you..." - **Using absurdly low-speed CW for "communications"**

Using your computer to ambush unsuspecting NDBs - **A brief description of how Spectran may be used when trying to receive NDBs.**

For more information on PSK31, MedFER, and LowFER experimentation, check these other fine sites:

The PSK31 "Official Homepage" - **Has articles, software, links to other pages**

"Novel Robust, Narrow-band PSK Modes for HF Digital Communications - **This is an excellent article about using PSK modes on HF**

The Longwave Club of America: "The World of Radio Below 500 KHz" - **Also covers MedFER operation**

The AMRAD LF Project - **AMRAD (Amateur Radio Research and Development Corporation) is doing some LF experimentation.**

The KA2QPG Longwave Page - Databases, files, and archives pertaining to Long/Mediumwave

K0LR's Page: Dedicated to LF experimenting and homebrewing (includes BPSK info, many other links, etc.)

The K3PGP Experimenter's Corner - Contains articles and links touching on everything "From VLF to Light"

Any comments or questions? Email to: ka7oei@arrl.net