

The Stanford University ELF/VLF Receiver

A tmospheric
W eather
E lectromagnetic
S ystem for
O bservation
M odeling and
E ducation

Preparatory guide
By Morris Cohen
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The following document is intended to describe the items involved and work associated with the reception of a VLF receiver. If you will soon be installing a VLF receiver from Stanford, the following guide will help you ensure you have all the preparations completed in advance.

Stanford University has been building and operating VLF receivers for decades, and the observations garnered from them through the years have formed the backbone of numerous experiments and studies on the ionosphere and magnetosphere. In recent years, a new version of the receiver was developed at Stanford that is substantially cheaper to produce, while at the same time improving the quality of the data and the ease with which the receiver can be set up and operated.

There are four main components to a complete VLF observation site. They are (1) antennas and cables, (2) preamplifier box, (3) line receiver box, (4) computer and software. The antennas gather the necessary data for the recording. The preamplifier box and line receiver box process the signals and pass them to the computer, run by a Stanford-developed software package

There are two antennas associated with the VLF receiver. The first is a GPS cable. This cable will need to be outdoors. It does not have any special requirements other than the fact that it must be mounted in a place with a view of the sky in order to receive signals from enough satellites. The purpose of the GPS antenna is to provide a very precise timing signal, so that the data can be sampled accurately, and synchronized with all other sites. It is often most convenient to simply mount the GPS antenna on the roof of a building. A picture of the GPS antenna is shown, as well as an example of how it might be mounted. It needs to be mounted within 60ft of the main computer's location..



The more important antenna, however, is the VLF antenna. Most Stanford VLF receiver sites utilize wire loop antennas. This simply means that a long wire is wound around, usually several times, so that it encloses an area. It then becomes sensitive to the magnetic field, which will induce currents in the wire. There are generally two loops, each

oriented orthogonal to each other, so that the receiver picks up magnetic fields parallel to the ground but in any direction. The following diagram illustrates this.

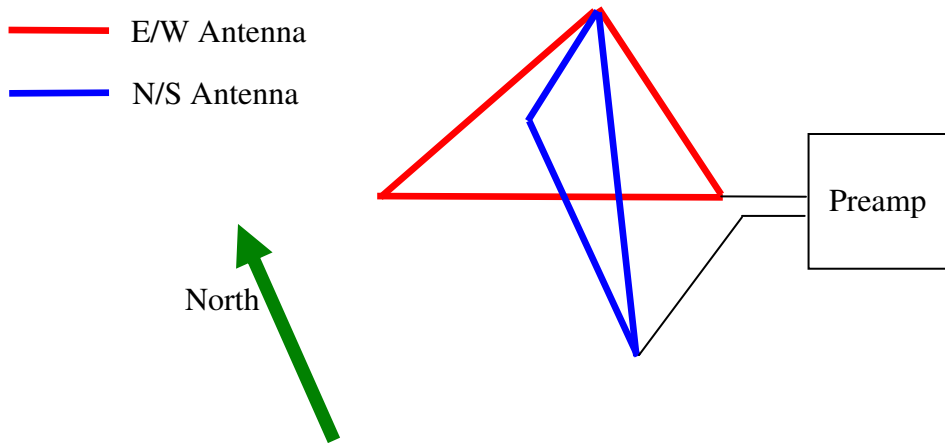


Figure 2: VLF Two Channel Orthogonal Magnetic Loop Antenna Configuration

Because the receiver electronics is designed to go along with a very specific antenna impedance, it is very important that the loop be built exactly according to specifications. There are, however, a number of different valid antenna sizes that can be used. The larger and heavier is the antenna, the more sensitive it will be. The choice of which antenna to use will depend on the quality of the site, and the VLF signals intended to be studied.

The following table shows several different dimensions that fit the specifications.

Some Valid Antenna Configurations

Base	AWG	Turns	Area	Weight	Wire	Cal Number
2.60 m	16	12	1.69 m ²	0.838 kg	75.3 m	2.785E-01
8.39 m	14	6	17.60 m ²	2.15 kg	121.5 m	1.450E+00
27.3 m	12	3	186.32 m ²	5.56 kg	197.7 m	7.675E+00
60.7 m	10	2	921.1 m ²	13.1 kg	293.1 m	2.530E+01
202 m	8	1	10201 m ²	34.5 kg	487.7 m	1.401E+02

These antenna sizes correspond to right isosceles triangles. The angle at the apex is 90 degrees, with the two angles at the ground forming 45° angles. The height will be half the base. It is intended to be set up with a single central mast, from which the wires hang. The cal number column is proportional to the antennas ability to pick up signals above the noise floor, though for some applications, even the smallest size is sufficient. Below are a few example pictures of Stanford installed wire loop antennas.



It is particularly important that the antenna be located in a quiet location, i.e., one not close to power lines, generators, or other sources of electromagnetic interference. This is especially important for larger antenna sizes. For this reason, the antenna can be placed as much as 1000m away for the quietest and most isolated of locations, though at most sites, 100m or so will suffice because moving away from one power line will eventually move you closer to the next one. Depending on the type of signals being studied, roofs of buildings may also be suitable.

Because of the specific nature of the wire loop antennae, the loops themselves are usually built at Stanford. However, the mounting apparatus is typically determined based on the specifics of the location, as well as the antenna size, and for this reason, it is necessary for a design for the mounting to be created and prepared for in advance by those in the area of where the receiver will be installed. Generally this is an easy task, simply requiring the erection of a central support, with the wires hanging down. For the case of a larger antenna, supporting guide wires will probably also be necessary to keep the structure stable against wind, rain, erosion, and the passage of time. However, in planning and constructing the antenna mounting, it is very important that no closed loops out of metal should be formed. Doing so will effectively create a parasitic antenna which will interfere with the function of the main VLF loop antenna.

The location of the antenna should be carefully considered and chosen well in advance, based on the desired size, the intended use for the data, weather and suitability for construction of the mounting apparatus, etc.

The loop antennae connect to an aluminum weather-proof box known as the preamplifier, whose job is to collect and amplify the small signals from the antenna without introducing any significant noise. The preamplifier weighs ~15 lb. A picture is reproduced below. It is generally mounted within 1-2 meters of the center base point of the loops. The pictures below show the preamp, and how it connects to the antenna loops.



The signals from each of the antennae are fed indoors with a cable. You will therefore need to determine how to pass two cables from the indoor location where your computer will sit, to the outdoor locations where the antenna is. This may include drilling holes in walls, or any other methods, and should be planned in advance. The cable that goes to the VLF antenna is approximately 2.5 cm in diameter, and the cable for the GPS antenna is ~2 cm in diameter.

Both cables plug into the line receiver, which is the box that performs some additional processing on the signal, along with the GPS management, provides power to the preamplifier, and passes the signal on to the computer for digitization. The box will be located within 1-2 meters of the computer. Pictures of the line receiver are below.



The line receiver will connect to the computer with two cables. The first is a serial cable, which will carry GPS information. The second is a specialized shielded cable that will carry the data signals, plus timing signals, to the

computer for digitization. The cable is made by National Instruments as part of their NI-DAQ series, the part number is SH6850.

The computer chosen will need to have a number of features in order to be used with the VLF receiver. It must have an open PCI slot, which will be used to install a digitization card made by National Instruments, the 6034E. Most desktop tower computers do have open PCI slot, but a few of the “slim” designs do not. It is also highly recommended that the computer have a serial port. If none can be found, you should acquire a USB/serial adaptor, and make sure it is working in advance.

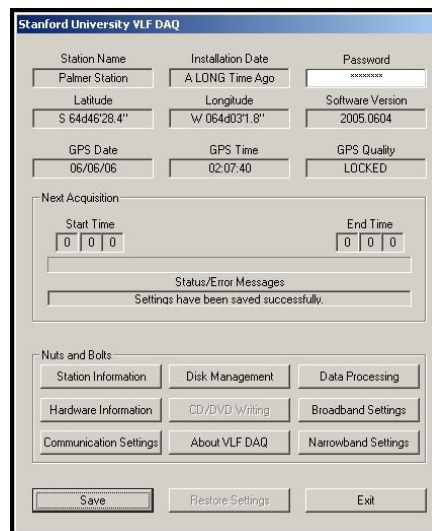
The computer should be a Pentium IV, with at least 256MB or RAM (512 preferred), and at least 80 GB in hard drive space. It is preferable, but not required, that the computer have one of the newer “multithreaded” processors in it, which will enable data to be posted live to the internet during recording. These requirements are in place because of the computational intensity of some of the real-time processing operations by the software, and the large hard drive ensures that there is plenty of space to store data temporarily before it can be transferred elsewhere. It is also very important that the computer be given full access to the internet, as this will allow the computer to post data live online, or send it via ftp to another computer, or for the computer to be remotely managed in the event of problems or software changes.

Finally, the VLF_DAQ software, designed shortly after the AWESOME receiver was completed, is designed to give a lot of flexibility in the recording schedule, the type of data recorded, where the data is kept and sent, etc. The primary purpose of VLF_DAQ is to enable collection of two types of data. The first is broadband, in which the entire datastream is saved as a single long waveform, at 16-bits, 100kHz, and for each antenna. This data accumulates quickly, at a rate of about 1.5 GB per hour. Because of this, broadband data is often collected only in “synoptic” format, for example, one minute out of every 15. During special campaigns and experiments, data can be acquired in a continuous format. The second is narrowband, in which case the amplitude and phase of a single frequency, corresponding to a VLF transmitter, is monitored. The software also demodulates the communication algorithm that is used by many of these transmitters, in order to accurately track the phase of the signal.

The VLF_DAQ software gives a lot of flexibility with regards to the management of the data. This includes, for example, ftp transfers of data, live posting of spectrograms to internet, automatic movement of data to an external hard drive.

VLF_DAQ is written for Windows, so the computer used for VLF_DAQ must have Windows XP installed.

A picture of the software’s main console is shown below.



Action Items

The following items should be completed or thought through in advance of the installation, in order for it to go smoothly and successfully.

1. Decide on a VLF antenna size
2. Select a location for the VLF antenna
3. Design a mounting apparatus for the wire loop – buy necessary parts.
4. Select a location for the GPS antenna
5. Determine how to run the two cables from outside to inside
6. Choose a location for the line receiver and computer
7. Measure length from VLF antenna to line receiver location, including extra length for the path of the cable
8. Acquire and set up a computer
9. Connect computer to the internet