AGO Field Manual

Dartmouth College LF-HF Receiver

May 10, 1996

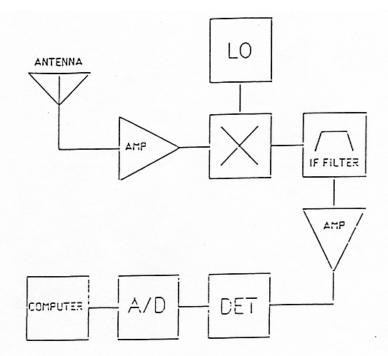
1 Introduction

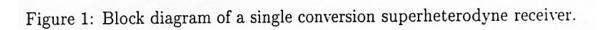
Many studies of radiowave propagation have been performed in the LF/MF/HF radio bands, but relatively few systematic surveys have been made of natural emissions in this part of the spectrum. The predominance of man-made signals in this frequency range requires a remote location and a radio receiver of specialized capabilities in order to search for natural emissions. For instance, a receiving system must be capable of both detecting very weak signals, and be able to step around or null out the known sources of interference, such as AM broadcast stations. Furthermore, a receiving system must be able to operate at remote locations with only limited human intervention.

The Automatic Geophysical Observatory (AGO) receiver was designed to run unattended for periods as long as one year constrained by severe power and data acquisition limitations.

2 Radio Receiving General Principles

The basic components of a single-conversion superheterodyne receiver are shown in Figure 1. An incoming signal is received by an antenna and amplified before reaching a mixing stage. At the mixer, the received signal is multiplied or heterodyned with a known local oscillator (LO) signal to establish an intermediate frequency (IF). In essence, it is the LO frequency that tunes the receiver to the desired reception frequency. The IF signal contains frequencies equal to the sum and difference of the frequencies of the LO signal and the input signal from the antenna. The difference frequency is selected using a tuned IF crystal filter. The resulting signal is amplified, detected, and digitized. There is no need for an automatic gain control in our receivers since we are looking for absolute signal strength and are not interested in keeping a constant output, as is typically desirable in commercial receivers. Furthermore, receivers with two mixer stages (double-conversion receivers) are also not desirable since the dynamic range of such a receiver is usually downgraded through the addition of the second mixer.





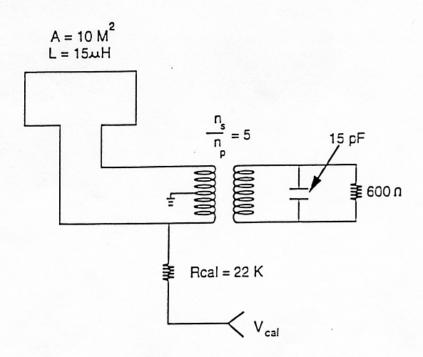


Figure 2: The effective circuit used to calibrate the receiver.

3 Antenna and Preamplifier

The AGO LF/MF/HF receiver employs a magnetic loop antenna which is less susceptible to locally generated noise than an electric dipole, especially when oriented to null out the strongest local signal. The loop consists of a single turn of wire arranged in a square between two vertical 12-foot-long 4 x4 posts placed 3 m apart. One horizontal wire runs along the snow, and the other connects the tops of the posts, so that the area of the loop antenna is 10 square meters. Figure 3 shows the antenna as deployed at AGO-P2.

The preamplifier is buried in the snow at the base of the antenna, with a pole or flag installed to make it easy to retrieve. A schematic of the most recent version of the preamplifier is included in the schematics portion of this manual. A critical component of the preamplifier is the calibration circuit, which allows the absolute level of the received signals to be calibrated. For this purpose, a broadband calibration signal designed to be near the top of the instrument s range is injected approximately hourly. This signal is detected by the receiver with its nominal gain, and then detected with the gain reduced by 20 dB. Using both of these detections, the gain and offset of the instrument can be accounted for, and the signals from the various AGO s can be compared. Figure 2 shows the effective calibration circuit. (The 600-Ohm resistor represents the input impedance of the preamplifier.)

The voltage at the antenna terminals of the loop antenna is related to the electric field of the impinging EM radiation:

$$V = \frac{A}{c} \frac{dE}{dt}$$
(1)

where A is the antenna area (10 m^2) , E is the electric field strength, and c is the velocity of light. Assuming that the antenna can be considered a perfect inductor at the frequencies of interest,

$$V = L \frac{dI}{dt} \tag{2}$$

where I is the current in the antenna, this leads to the following relation after integration

$$LI = \frac{A}{c}E\tag{3}$$



Figure 1: The 10 m^2 loop antenna installed at AGO-P2, Antarctica. The AGO facility, along with two Scott tents, can be seen in the background. The preamplifier is buried several feet under the checkered flag in order to keep it at a constant temperature.

If a calibration resistor R_{cal} is placed in series with the antenna such that $I = V_{cal}R_{cal}$, the calibration voltage (voltage at the antenna terminals) becomes

$$V_{cal} = \frac{AR_{cal}}{cL}E\tag{4}$$

For our 10^2 loop antenna, the electric field strength (V/m) and V_{cal} are related through the following equation,

$$E = 0.01 V_{cal} \tag{5}$$

which was obtained by substituting the appropriate measured quantities into the above equations.

The least detectable signal of this receiving system corresponds to $V_{cal} \approx 50 \mu V$. Therefore, the power spectral density of the received signal at the loop antenna is $5nV/mHz^{\frac{1}{2}}$, assuming a 10 kHz bandwidth.

4 Receiver

The AGO LF/MF/HF receiver is located in the observatory, 300-500 feet distant from the antenna. Figure 4 shows a block diagram of the AGO receiver. Power from the DAU comes in on the specified connector and is converted to the required ± 10 Volts and ± 5 Volts DC on the power supply board. The mixing of the signals occurs on the receiver board; the LO signal used in the mixing is produced on the local oscillator board. The signals are compressed and prepared for the DAU on the compression board.

The receiver is tuned by adjusting the frequency of the LO signal. The sequence of frequencies to be tuned is programmed into an erasable programmable read only memory chip (EPROM), which is then clocked at the desired frequency-switching rate. In the AGO s, this EPROM is actually clocked at 20 Hz, twice the rate at which bytes are actually transferred to the DAU. The receiver compresses samples by a factor of two and passes one byte to the DAU each 0.1 s which most of the time represents two samples. The EPROM contains a sequence of 72000 steps, which are clocked at 20 Hz to control one hour of measurements. At the end of the hour, the EPROM is reset, and the cycle repeats. (The EPROM also contains a test program, to be used only for debugging, which is enabled by setting one address bit high using a DIP-switch.)

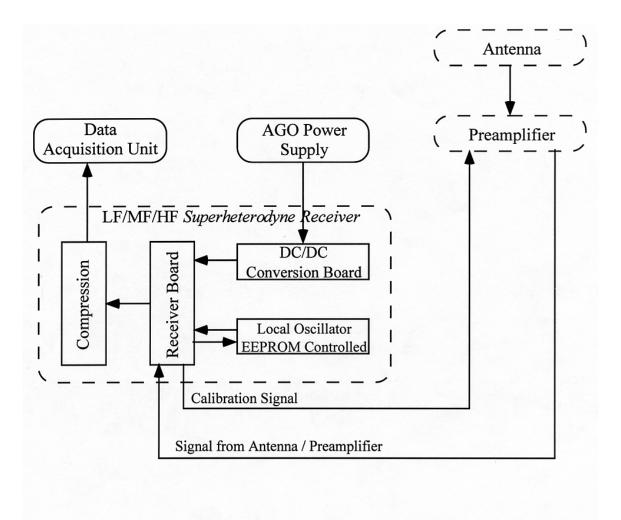


Figure 4: A block diagram of the AGO Receiver

The receiver as currently configured measures 116 frequencies from 30 kHz to 4.5 MHz. The frequencies are not spaced linearly but are arranged to optimize reception of known natural signals such as auroral hiss and auroral roar. Furthermore, the frequencies are arranged in two sets of 58 frequencies with each of these subsweeps ranging from the low end of the frequency range to the high end but consisting of frequencies slightly offset. Using sub subsweeps provides higher effective time resolution for detection of relatively broadband signals. Table 1 at the end of this section gives the list of the 116 frequencies in the right column are sampled. The 20-Hz data rate (with compression) implies that a full sweep of 116 frequencies is obtained each 5.8 s, and a subsweep of 58 frequencies is obtained each 2.9 s.

Data compression is critical to the performance of the AGO LF/MF/HE receiver. The compression works by transmitting periodically a reference sweep of 120 bytes which provides 8-bit measurements of the logarithm of the received signal strength of each of the 116 frequencies (plus two sync-byte plus two filler bytes). Following the reference sweep, 44 delta-sweeps are transmitted. In these, only the change in each signal strength is transmitted, compressed to a 4-bit number. Hence these 44 sweeps are require only 2640 bytes (44 times 60; two sync-bytes are attached to each delta-sweep). Following these delta sweeps, another reference is transmitted (which requires 120 bytes), then 44 more delta-sweeps, and so on. Once an hour, a calibration sweep is performed, consisting of 120 bytes: an 8-bit sample of the calibration signal at each of the 116 frequencies, with the receiver at full gain for even samples and with gain reduced by 20 dB for the odd samples; plus two unique sync-bytes, plus two filler bytes. Thirteen blocks consisting of a reference and 44 delta-sweeps are transmitted between each calibration sweep; the result is a package of 36000 bytes transmitted to the DAU every hour, providing exactly the quantity of data (0.1 byte per second) allotted to the LF/MF/HF receiver.

All of the numbers cited above — controlling the frequency of reference sweeps, calibration sweeps, etc. — can be changed by re-programming and replacing the EPROM. The number of sampled frequencies as well as the actual frequencies sampled may also be changed this way. If in the future it becomes possible to store a larger quantity of data, the data rate can easily be increased by up to a factor of ten by adjusting DIP switches in the unit (without any change of hardware).

The output of the receiver is available as an analog signal on the front of the receiver box, and instructions in this manual tell how a two-channel oscilloscope can be used to produce an image on the screen of power versus frequency. Furthermore, a computer program has been written for DOS, which decodes the digital output of the receiver and produces a power-versus-frequency plot on the computer screen, which updates in real time. To use this program, the digital output of the receiver must be connected to the serial input of the computer. Figure 5 shows an example of a spectrum generated using this program in combination with one of the AGO LF/MF/HF receivers in the lab at Dartmouth. A version of this program is being prepared which will review a file of LF/MF/HF data extracted from the DAU. If a file can be produced which contains sequentially the bytes provided by the LF/MF/HF receiver, these bytes can be decoded and displayed on the screen as power versus frequency, updated either by the operator or at a rate fixed to the computer clock. All three of these tools will enable the operators in the field to determine whether the receiver is functioning.

The AGO-based LF/MF/HF receivers should yield the most sensitive measurements to date in this frequency range. The capability of simultaneous measurements between several AGO sites also will enable the temporal and spatial effects of natural LF/MF/HF radio emissions to be studied. Finally, since each AGO will consist of a core group of synchronized geophysical experiments, correlations between data sets which are exactly co-located can be easily made.

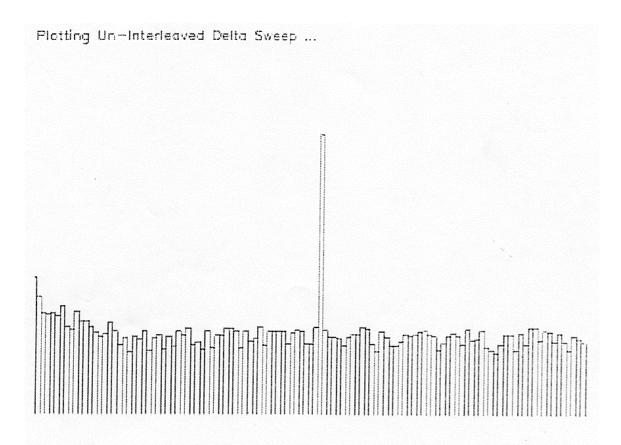


Figure 5: A single spectrum of LF/MF/HF data measured in the lab. Peaks represent injected signals. In the AGO environment, a few similar peaks may result from interference from other AGO instruments; however, the spectrum may be mostly quiet.

All Frequencies in kHz	
1st Sub-	2nd Sub-
sweep	sweep
30	40
50	60
70	80
90	100
110	120
130	140
150	160
170	180
<u>190</u> 210	200
210 230	220
230 250	240
270	280
290	300
310	320
330	340
350	360
370	380
390	400
420	440
460	480
500	520
540	560
580	600
620	640
660	680
700	740
780	820
860	900
940	980
1020	1060
1100 1260	1180
1420	1340 1500
1420	1660
1740	1820
1900	1980
2060	2140
2220	2300
2380	2420
2460	2500
2540	2580
2620	2660
2700	2740
2780	2820
2860	2900
2940	2980
3020	3060
3100	3140
3180	3220
3300	3380
3460	3540
3620	3700
3780	3860
3940	4020
4100	4180
4260	4340 4500
4420	

Table 1: Sequence of frequencies measured in the current version of the AGO LF/MF/HF Receiver. The sequence runs down the first column, then down the second column (116 frequencies total).