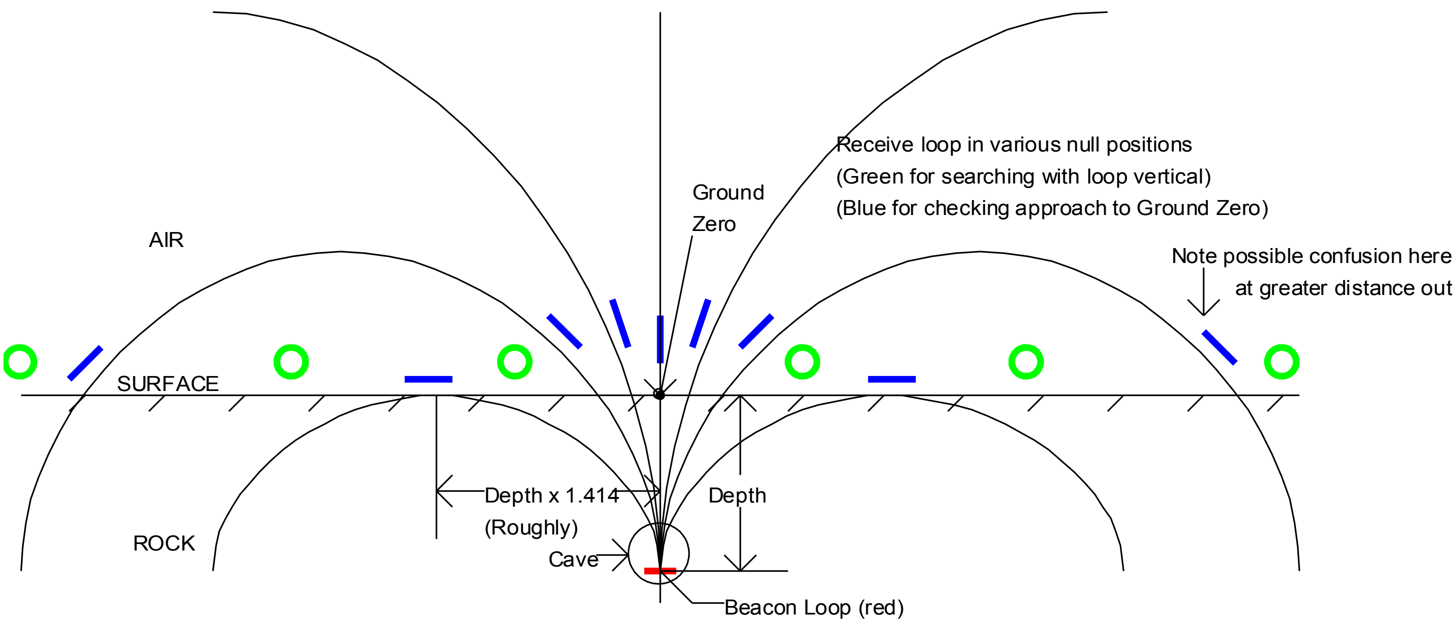
REAL TIME TRACKING OF AN UNDERWATER BEACON

Using the shape of the magnetic field

The goal is to track Endurance from the surface as the vehicle wanders under the ice, using a low power magnetic field radiating from the beacon while in it's stowed position. Tracking requires practice and an understanding of the shape of the magnetic field! If the tracking is successful, the approximate location of Endurance will be known throughout the run. If the receiver operator (or someone following him) carries a GPS receiver, the complete track of Endurance can be recorded. If a failure occurs, and Endurance drifts up against the ice, it can be quickly located even if the beacon fails to deploy and switch itself to full power.



MAGNETIC FIELD SHAPE FURTHER FROM GROUND ZERO
(Side view looking horizontally)
Figure 1

The difficulty with tracking Endurance is the shallow operating depth, which confines the portion of the magnetic field with good directional characteristics to very small area on the surface. Refer to figure 1 (which was originally drawn for cave locating). For example, if Endurance was operating 15 feet (4.5m) below the surface of the ice, to obtain good directional nulls for tracking the operator of the Radiolocation receiver would need to stay within about 50 feet of Ground Zero (the point on the ice directly above Endurance). However, to keep track of how far he is from Endurance, for this example he must stay within 21 feet. The reason is that at 21 feet (15 x 1.414) the magnetic field has transitioned from vertical (at Ground Zero) to horizontal. By monitoring the tilt of the field, the operator can position himself just behind Endurance without overshooting. This requires constant attention. It is much easier to track a beacon at 100 feet (30m) depth!

Tracking Procedure

1. Read and understand the paper "*LOCATING A SHALLOW RADIOBEACON UNDER ICE*" before continuing. Test and align the receiver, using the procedures in Appendixes A and B, prior to deploying Endurance. The signal strength readout will not normally be used during real time tracking, but it will be useful to help relocate Endurance if the operator accidentally gets too far away to obtain good directional nulls.
2. For real time tracking, Endurance will be deployed with the radiobeacon operating at a low power level but in its stowed position. The magnetic field may be somewhat distorted by being so close to so much metal, but it should still be good enough for tracking purposes. Set the receiver RF and audio gains to reasonable levels. If the RF gain is set too high, the receiver will overload (red LED lit most of the time), causing the nulls to be abrupt instead of smooth as the vertical receive antenna is slowly rotated. If the signal is well above the noise (quite likely except perhaps very close to the hut), the bandwidth can be changed from the normal 1 Hz to the 32 Hz mode. This will make tracking <u>much</u> easier by speeding up the receiver's response time. The receiver operator will want to quickly position himself directly over the beacon as soon as Endurance moves out from under the deployment hut. This is tricky when working with a moving object!
3. Successful tracking requires the use of two alternating techniques in order for a single operator to stay the proper distance from the beacon. The first technique is to slowly (and repeatedly) rotate the vertical loop back and forth through the signal null that defines the LOP so that the operator can walk in the same direction that Endurance is moving. This is shown in Figure 1 by the green circles, which represent the loop in null position at different distances along a LOP that is in the plane of the page. The optimum distance is shown by the circles closest to Ground Zero. For our purposes, assume that Endurance (and Ground Zero) are moving from right to left, with the operator following behind.
4. The critical part is staying the optimum distance behind Endurance. To use the second technique, the operator must periodically rotate the loop 90^0 so that the plane of the loop is perpendicular to the LOP (i.e. to the direction of travel). The operator then tilts the bottom of the loop towards the direction of travel until a "field angle" null is found. The null may be quite broad, but it will clearly show the angle of the magnetic field. This is shown in Figure 1 by the blue lines, which represent loops loops turned perpendicular to the page. The optimum angle to lag behind Endurance probably lies somewhere between 30^0 (very close to Ground Zero) and horizontal (~1.4 times the beacon depth). If you overshoot, the field angle null will occur with the bottom of the loop towards the operator.
5. An alternative method is to have a second operator walking slightly ahead and to one side of the tracker. The second operator's LOP will cross the track close to Ground Zero. This makes the Tracker's job easier, and provides real-time redundancy for both receiver and operator.

6. If Endurance stops moving, the operator can precisely locate the vehicle and remain at ground zero. See page 4 of the "*Locating Ground Zero*" paper for the procedure. The loop can be periodically rotated and tilted to check for movement.

APPENDIX A
Receiver Audio Tone Null Balance

Prior to use, The receiver should first be equalized to roughly the temperature it will be exposed to while in use. Next, disconnect the antenna and turn & switch the RF gain controls to minimum. Now carefully adjust the front panel null control for minimum audio tone level in the headphones. Turn up the volume control as necessary to hear the tone, which should just about disappear into the background noise. If the tone does not get this low, then use a small screwdriver to make a very small adjustment to the internal null pot, then re-adjust the front panel null. These 2 adjustments interact. Normally, the internal null pot seldom needs adjustment. The RF gain can now be returned close to maximum and the antenna reconnected.

APPENDIX B
Receiver Alignment to Insure Correct Signal Strength (DVM) Readout

The receiver must be tuned very close to the frequency of the beacon in order to phase lock properly and give a steady DVM readout of signal strength. The beacon frequency is not adjustable, but will vary slightly with temperature. Because the crystal oscillators drift with temperature, prior to starting this alignment, the receiver should be close to ambient temperature and Endurance (or just the beacon) close to 0 degrees C. It is important to understand that the audio tone portion of the receiver will work perfectly even when the DVM readout is not functioning.

If the receiver is phase-locking properly, while receiving the Beacon signal from ~30m away, the green phase-lock LED will light, and stay lit, while the DVM will settles on a steady positive value (no - sign in front of it). Now switch the DVM to "PLL Adjust" and **very slowly** turn the front panel frequency adjustment until the DVM reading is as close to zero as possible, hopefully under 100. Note that this PLL reading will not be steady, which is normal.

If the receiver is not phase-locking properly, the DVM reading will not settle on a steady value, and may become negative for a time. The green phase-lock LED may be blinking slowly. Slowly turn the front-panel frequency adjustment while watching the green phase-lock LED, which should be blinking slowly on and off. Tune until the blinking becomes slower and finally stops with the green LED lit and a steady, positive, DVM reading. This will seldom need readjustment, but <u>can</u> be done in the field during a Radiolocation if necessary.