OPERATING INSTRUCTIONS for GOLDSCAN 5

The GOLDSCAN 5 metal detector is a completely revised and updated version of the earlier successful range of Goldscan detectors that were first produced in 1983. The Goldscan was originally designed as a sensitive and powerful P.I., which had the additional benefit of being able to cancel out the signals caused by iron mineralised ground. In this respect it was the world's first ground balancing pulse induction metal detector. It was last produced in 1995 as the Goldscan 4, and now with the addition of many new circuit ideas, improved coil systems and upgraded performance, it is back, as a detector that will have many applications, not only inland, but on mineralised and non-mineralised ocean beaches as well.

Before use, or doing any tests, the Nickel Hydride battery pack must be installed in the detector. First remove the transparent lid by giving each corner screw a ¼ turn anti-clockwise. Fit the battery by gently easing into place in the recess between the foam retaining pads. To avoid straining the plate, enter one end of the battery first, at an angle, and then press into position along its length. Position the connector lead so that it is in the bottom right hand corner, adjacent to the fixed connector on the metal top plate. Plug the two together. The battery should come to rest flat on the metal plate, to give sufficient clearance for the lid to be repositioned. Lock each corner screw ¼ turns clockwise, pushing down against the spring, to secure.

Batteries are shipped uncharged, so with the battery installed in the detector, plug the jack on the charger power supply into the headphone socket on the top panel. Next, plug the line plug into a 110/240V ac outlet. The **RED led indicator** should glow to show that charging is taking place. The charger should be left on for 15 hours initially, to give a full charge. Both the charger power supply and the detector with become slightly warm during this charging period. The detector gets warm because the main charging regulator is in the control box, and uses the aluminium base plate as a heat dissipater. When approaching full charge, the battery also gets warm.

When the battery is charged, the shaft can be assembled and the coil mounted. The coil cable can be secured to the shaft by the Velcro straps. The cable can be run straight up the shaft, or wound spirally around it. It is not recommended to tightly and closely coil the cable on the shaft as this can strain the internal wires. Just a smooth open spiral is all that is required to keep the cable secure and not flop about.

Mount the probe in the clips provided and plug the lead into the three pin connector on the bottom panel. Do up the locking sleeve, but do not over tighten. This just serves to hold the connector securely together, but does not affect the electrical connections.

Plug the coil lead into the 5 pin connector on the bottom panel. Observe the above comment about over tightening.

On the top end panel is the **THRESHOLD** control, which is combined with the ON/OFF switch. Having switched on, this sets the audio threshold level in the 'phones, which are plugged in to the jack socket. This is normally set so that the background tone is just faintly audible. However, if there is a high background noise level from wind or surf, this control can be advanced a bit without affecting the unit's sensitivity.

Also on the top end panel is the **VOLUME** control. This is used to adjust the maximum volume which the detector will give on a strong signal. This prevents "ear bashing" with sensitive headphones. Using this control, weak signals are affected less than strong ones, so that sensitivity loss is minimised. The volume and threshold can be balanced to give a comfortable audio threshold level.

On the side panel there are four controls and a switch. Starting at the bottom end, there is the sample pulse delay, **P.DELAY.** It alters the time between the end of each transmitter pulse, and the start of the receiver sampling period. Sampling as close as possible to the end of the transmitter pulse gives the highest sensitivity to small objects, or objects of low electrical conductivity. For highest sensitivity to small or thin targets, set this control at 10uS. If less sensitivity is required, or to suit local conditions, such as if the detector is to be used on a salt wet beach, a higher setting can be used.

TX FREQ. This gives a small adjustment to the transmitter pulse frequency, or rate. This is used to counteract some interference from outside electromagnetic sources, such as radio stations and power lines. If the audio warbles in a repetitive way, just alter this control slightly, and find a point where the audio is most stable.

RANGE. This adjusts the receiver amplification, and hence, the detection range. Normal setting is with this control midway. However, in good detecting conditions with low mineralization, this control can be advanced more toward MAX. In conditions of high mineralization, or electromagnetic noise, this control can be set to lower values to get a smoother threshold.

GB/DISC. This control is used to set the detectors ground balance point. It is only operative when the toggle switch next to it, is in the ON position. The setting of the GB control will be discussed in detail below.

GB/DISC ON - OFF control. This is used to either enable, or disable, the ground balancing feature. In the OFF position, the detector reverts to a "straight" PI. This will also be discussed in detail, with the operation of the GB control.

PROBE/COIL switch. This is located on the bottom panel between the two connectors. This switches between the main coil and the pinpointing probe. The toggle on the switch faces whichever connector is active.

Mount the detector control box on the waist by means of the belt supplied. Set the controls as follows.

P. Delay - mid position.
TX Freq - mid position
Range - mid position
GB/Disc - mid position.
GB Switch - Off.

Switch the detector **ON** at the **THRESHOLD** control and turn up until the threshold tone is audible in the background. Note that the BATTERY METER should read well into the green area. **Note -** Always check that the volume control ***is at least half way up before setting the threshold level***. If the volume control is near minimum, then you have to set the threshold level too high, to get an audible signal. The result of this is that there is a substantial loss of sensitivity.

This is when setting up in the Ground Cancel mode

It is possible that the threshold audio could be set at too low of a level to achieve maximum performance. Try setting the volume a full clockwise, and adjust the threshold for a strong audio response. It will smooth out the threshold as you do this. Return the volume on the detector to a more comfortable position, trying to stay near the mid point.

Scan the search coil over a coin and hear the response. It is best to do this test well away from buildings and electrical equipment, to avoid interference. Note that as the coil sweeps over the target, the audio volume gets louder, and also the pitch of the tone rises. The GOLDSCAN 5, unlike its predecessors, is a **motion detector,** so the search must be swept continuously to maintain the signal. If the coil is held stationary over a target, the response will zero out, back to the threshold level.

Take the coin away and lower the coil to the ground. If there is still a response, it means that the ground probably contains iron minerals. Move the coil around to scan different areas of ground, just in case there is a piece of metal that is confusing things. Switch on the **GB/DISC** by putting the toggle switch to **ON.** The ground response should now be less. Move the coil vertically up and down, to within an inch of the ground surface. Slowly adjust the GB control until there is no response. The detector is now ground balanced.

Try a range of different objects to detect, including some ferrous targets. Note that the audio pitch will rise on some targets and fall on others. Generally, small non-ferrous targets will give a rising pitch and larger ones will give a falling pitch. The majority of iron objects will give a falling pitch which is often irregular in nature.

PROBE OPERATION.

Bury a target a few inches down in the ground, or you can just place a target on the surface to try the probe. Operate the toggle switch on the bottom panel, between the coil connectors, so that the toggle is pointing to the probe connector. The main coil is now inactive and the probe is live. The audio threshold will automatically adjust to the probe, which can now be used to pinpoint a target. Scan the probe tip an inch or so off the ground or a couple of inches if the target is on the surface. Note the sharp response and the accurate pinpointing that results. All the control settings that were used on the main coil, also apply to the probe. Note that in strongly iron mineralised ground, the possible comfortable mineralized control may need to be adjusted slightly. Having finished with the probe, just switch back to the main coil.

MORE ADVANCED OPERATION

The above tests will familiarise the user with the basic characteristics of the GOLDSCAN 5. However there are many further things that can be done in the field; although some of them will take a little time to practice.
There are several adjustments that can be made to optimise the performance of the detector.

For the highest sensitivity to small targets, set the **P. DELAY** to a lower value, maximum sensitivity being **10.** For less sensitivity to small targets, use a higher value up to **25**. If this control is changed, the **GB/DISC** control will need readjusting. See under GB setting.

If there is excessive fluctuation on the audio, try altering the **TX FREQ** control. You can often find a quiet spot if the interference is from other nearby detectors, local radio transmissions, or power line harmonics. Often, only a small adjustment is needed. This control does not have any other effect on the performance of the detector. If noise is severe, or the maximum detection range is not required, the **RANGE** control can be turned back, until the threshold is smoother.

For beach use. It may be preferable to search with the GB switched off. This gives a slightly quieter threshold for initial searching, and then, when a target is found, the **GB/DISC** can be switched in to help identify the nature of the target.

The control which is central to the operation of the Goldscan 5, particularly in iron mineralised ground, is the **GB/DISC** control.
In non- mineralised or lightly mineralised ground, this control has no effect, except that it can help to identify targets. The more strongly the ground mineralization becomes, the more critical the setting of this control. As a rough guide, When the P.DELAY is set to 10, the ground balance setting will be at 9 o'clock on the GB/DISC control. When the P.DELAY is set at 25, then the GB/DISC control will be at 3 o'clock. For intermediate P. DELAY settings, the GB point will also be in between. i.e. 12 o'clock on P.DELAY is also 12 o'clock on GB/DISC.

Further adjustments to the **GB/DISC** control may be necessary if certain types of hot rock are encountered. Conductive hot rocks cannot be tuned out on the GB control, but can often be removed by use of the **P.DELAY** control. Small object sensitivity will, of course suffer if this control is turned back too much. If it is an iron mineralised hot rock, then a small adjustment will often eliminate the signal, without materially affecting the ground balance.

AUDIO RESPONSES

This area is perhaps the most difficult to describe, but is certainly a valuable feature of the Goldscan. The following are descriptions of the audio responses that have been posted on Internet Forums.

IRON I.D.

The iron ID on the GS5 is a by-product of the ground balancing circuit. Fortunately, the signal decay from iron mineralised ground is predictable, no matter where in the world you may be. Also it is nearly the same for a wide variety of objects. For example, I can ground balance the signal from a tray of Australian laterite, and the setting will be almost the same for a fired clay British house brick, which will be almost the same as for a lump of volcanic lava from Hawaii, or the Canary Islands. What does change is the signal strength, with the Australian material giving the strongest signal. The detector circuits have, therefore, to cope with widely varying signal strengths, without the balance setting being upset, which would result in a false signals or a noisy background.

Having "tuned" out the ground signal, the decay from metallic targets is either faster or slower and does not balance out. Which side the target signal falls, depends on its size and conductivity. Small gold will fall one side (faster decay), as will most cupro-nickel coins. Large gold, most silver and copper coins will fall on the other side (slower decay), as does most iron. Gold varies a lot on conductivity, depending on what metals it is alloyed with. Only a small percentage of other metal, even good conductors such as copper or silver drastically reduces the conductivity and shifts the signal decay to the "fast" side.

Targets that have a faster decay than the ground matrix will give a rising tone, plus an increase in loudness as the object gets nearer the coil. Targets that have a slower decay will give a falling tone, also with increase in loudness the closer to the coil they are.

For the sake of simplicity, when the audio tone rises, this was described as a WEE. When the audio tone falls; a WOO.

Goldscan 5 either does a WEE, or a WOO and only rarely, both. A WEE indicates a target that has a faster decay than the iron mineralised ground. This would include most small and some medium nuggets. A WOO, indicates a target that has a slower decay than the ground. This would include large and more conductive non-ferrous targets, and most iron, down to the size of a hardboard pin. Because the ground balance circuit has cancelled out the signal due to iron minerals, it also reduces considerably the signal due to metallic iron. What is left is usually an irregular WOOWOO response which can be distinguished from the smooth WOO of a larger non-ferrous target. As mentioned above, certain items will give a WOOWEEWOO response, and these are flat iron or steel objects. Tin lids, flat sided cans, and even copper plated steel coins, come into this category. This is because, as the coil scans across the object, the first response is magnetic, which has a longer decay, and generates a WOO. As the target approaches the coil centre, and the magnetic field from the coil is cutting the target vertically, the decay shortens, as it is then mainly eddy currents rather than magnetic signal. This generates the WEE. As the coil passes so that the target is now leaving the coil, the magnetic decay dominates again, giving the departing WOO. You have to sweep a bit slower to determine this, as the WEE response is usually stronger and longer, but with time and practice it is a useful diagnostic feature to identify flat iron. Like Reg said, nothing is perfect, and because iron and steel objects are so diverse, and usually in various states of decomposition and orientation, there are bound to be many targets that respond otherwise. I have found that hardened steel objects often give just a WEE response. i.e. fishhooks on the beach.

The Goldscan audio response also changes in amplitude, or loudness, in about equal measure. You can set the threshold to give just a comfortable background level and listen for changes both in the tone and strength. Volume level is more than adequate for most phones, and a volume control knob adjusts for a comfortable maximum level, without affecting low level signals quite as much.

Check decay rates for gold & iron.

COILS.

Standard coils made by Pulsepower Developments for the Goldscan 5 are, 11in and 8in mono, although provision has been made for future DD coils. However, the Transmit/receive circuitry has been designed to accept coils from other manufacturers; notably Minelab and Coiltek. These are coils that operate with the **SD and GP series of detectors only.**

This is made possible by the use of a current regulator in the transmitter that sets the current at a predetermined level, irrespective of the resistance of the coil winding. Not all alternative coils have been tested by Pulsepower, but Minelab 11in mono, ML 11in DD, Coiltek 14in DD, Coiltek 14in mono, and Coiltek 17 x 10 DD, all work well. A small adjustment of the P. DELAY control may be necessary, as alternative coils may not work at 10uS delay in every case.

CHARGING

When the battery indicator crosses from the green to the red, charging the battery needs to be done soon i.e. there is 30 - 60 minutes of detecting time left. When the indicator is halfway into the red, then charging must be done as soon as possible. From the meter being halfway into the red, a full charge takes about 15 hours. With nickel hydride batteries, top up charging is permissible, if needed.

To perform the charging operation, plug the jack on the end of the charger power supply lead, into the phone jack socket on the short lead at the top of the detector.

Check that the detector is switched OFF before charging the battery.
Plug the mains/line plug on the power supply into a wall socket. Be aware that the charger gets warm when operating. This is quite normal. The charging power supply operates from all a.c voltages from 100V - 240V. When charging is in progress, the **red LED** on the top panel is illuminated.
Never leave the detector for a long period with batteries that are almost discharged. Always charge up for a few hours before storing the detector.

Both the search coil and the probe can be submerged in shallow water. However, although the electronics is weatherproof and splash proof, it must not be submerged on any account.

The retaining collars on the connectors for both the coil and the probe should only be tightened finger tight. These only serve to retain the two halves of the connector together and have no effect on the electrical connections. Over tightening could cause the plug on the detector to eventually come loose. The threads on these collars should be kept clean by brushing out occasionally with an old toothbrush. A trace of lubricant such as WD40 helps to keep the thread running free.

UNDERSTANDING THE PI METAL DETECTOR

BY REG SNIFF

One of the more popular metal detectors used for nugget hunting today is a type of detector commonly called the Pulse Induction or PI for short. A lot has been written on the general principles of operation but many questions are still unanswered or not answered completely about this strange machine. Also, there are a lot of misinterpretations of information that has been written about PI's and how they work.

As an example, in some books there is a statement that a PI does not "see mineralization" so it is therefore a great detector to use in mineralized areas. Is this really a true statement? The answer is both yes and no.

PI's basically do not respond to the typical iron mineralization such as magnetite or black sand. However, other minerals of the same family can and many times do cause a response. Iron oxides such as maghemite, clays, and other things such as salts commonly found in the ground can cause a PI to produce a rather strong signal. So, generally a very sensitive PI, normally used for gold hunting will respond to ground signals, especially if it does not have some form of ground balancing circuitry built in.

One question that is often asked is what is the operating frequency of a PI. This question is often asked by someone who is trying to relate their knowledge of VLF's to the PI. Unfortunately, because of the nature or differences between types of detectors, comparing a PI to a VLF is sort of like comparing an apple to a potato, so trying to relate the operating frequency of a PI to a VLF or sensitivity to small gold is of little value. The differences between the two types of detectors or the affects of their operating frequencies are quite dramatic so it is best to not try to use the same standards when trying to determine certain things about a PI.

As for a PI, the pulse rate or pulses per second (pps) refers to the number of high current pulses that occur over the time specified. Rates vary from a few hundred to several thousand per second: Generally, more pulses allow for a little better averaging and thus a little better signal to noise ratio. However, a detector will have a tendency to consume more current with a higher pulse rate. A faster pulse rate doesn't mean a detector will detect small gold better. In fact, it is quite easy to build a PI that has a very low pulse repetition rate (PPS) that is very sensitive to very small gold while designing a PI with a high PPS that is not sensitive to small nuggets.

Now, both PI's and VLF's will detect metals, respond to different ground conditions, and even respond to salt water. Both use a coil, specialized circuitry and usually generate a similar output to indicate some object has been detected However, the techniques, circuitry and in many cases, the coils are dramatically different.

VLF's generally produce a relatively low power continuous sinewave into the transmit coil and, analyze a signal received with a separate receive coil winding. A signal from an object will increase the amplitude of the receive signal level but will also shift the receive signal with respect to the transmit signal. Thus, an object can be analyzed by not only the intensity or amplitude increase of the signal but by just how much the signal has shifted.

VLF's generally operate at a single frequency but can be produced to operate at different frequencies. However, each frequency has to be analyzed as if it is the primary frequency and as such, both the signal strength and the shift are used to determine the presence of an object as well as type of metal.

PI's are a different beast all together. Instead of transmitting a low power continuous signal, the PI generates a brief high current pulse to energize the coil and this pulse is repeated at some nominal repetition rate, which can vary from a few hundred pulses per second to thousands per second.

The technique to determine whether an object is present is to analyze the signal coming from the receive coil shortly after the high current pulse is turned off. This is done by sampling the signal coming from the coil some time after each high current pulse. This time after the pulse is often referred to as the delay time Remember, on a PI, the transmit coil may become the receive coil once the transmit signal is turned off so there is no need for a separate receive coil winding. This type of coil is often referred to as a Mono coil.

PI History

There has been considerable work on PI type detectors since the early 1960's. One of the main reasons for their design was so they could be used for archaeological purposes. Most of the work in the evolution of the PI occurred in Europe during those early years, and much of this work was done in England by a young engineer by the name of Eric Foster.

As a result of his involvement with PI's during their early years, Eric Foster began his own business building PI's for industry as well as the consumer market. Many of his initial designs are the cornerstones of some of the PI's used today. Sometime in the early 1980'S, Eric Foster built a PI with ground balancing capability and a rudimentary form of discrimination. He also built a much better discriminating PI around the same time frame.

Minelab was the first to introduce a PI specifically designed for gold hunting in the US some time the 1990'S. The introduction of the SD 2000 really started the serious use of PI's to search for gold even though people began using Eric Foster's detectors for nugget hunting sooner in Australia. What made this ML PI detector excel was the introduction of the use of a DD coil on a PI. The DD coil had the ability to eliminate much of the ground problems making it a quieter choice. One other major advantage of the ML was it operated and sounded much more like a VLF. A PI equipped with either a mono or a DD coil will ignore many hotrocks and have additional depth of detection. However, this depth advantage is greatly reduced in very quiet ground.

Eric Foster's ground canceling detector had a putt-putt type audio, required the operator to retune the detector frequently, and had several different modes, some of which made the ground balance mode seem much less sensitive. Also, since only a mono type coil was available, some of the more severe areas still caused problems even when the ground balance was used. As a result, Eric Foster's ground canceling PI, the Goldscan, never really caught on.

Strange as it may seem, one of the first US patented designs using a high current pulse to detect metals that also had ferrous/non-ferrus discriminating capabilities was designed by George Payne in about 1978 or so. This design not only would distinguish iron objects but also had a basic form of ground balance. This strange design used a bi-polar form of pulsing, which was also unique. Unfortunately, because of the high current necessary for operation and thus, the need for a very large battery, the design was never produced and sold. Instead, American manufacturers focused on developing VLF's for both coin and gold hunting.

How do PI's really work and what makes them sensitive to small gold?

As stated earlier, PI's operate on the principle of generating a large current pulse in the coil and then analyzing the signal in the coil a short time after the pulse is turned off. This cycle is repeated on a continual basis.

As simple as this sounds, the design is quite critical. The key to increasing the sensitivity of a PI is to turn off the current pulse as soon as possible, and then stopping the resulting high voltage spike as soon as possible.

By nature, a PI coil is an inductor and as such, any immediate disruption in current will cause the inductor to produce a very large voltage spike in its attempt to keep the current flowing. This high voltage spike is a side affect of the current disruption that has to be dealt with as quickly as possible so any signal from a metallic object can be distinguished.

When the current is flowing in the coil, a magnetic field is generated that expands from the coil. When this field encounters a metallic object such as a gold nugget, current begins to flow in the nugget as the result of this magnetic field. When the current suddenly stops in the coil, the coil field collapses which in turn causes the current in the object to collapse. This secondary collapse of current in the nugget causes it to produce its own field that now generates back to the coil. This target signal ultimately adds to the collapsing coil signal, thus making the coil signal change very slightly.

The signal strength, and just as important the duration or time of the signal produced by a detected object is a function of the size, shape, and actual composition, among other things. Gold and other low conductive materials may produce a strong signal but the duration of the signal is much shorter than a signal from something like a piece of iron, copper or silver. Very small nuggets, in the few grain range, not only generate a very small signal, but also a very short signal.

Small iron objects, on the other hand, will produce a much larger signal as well as a much longer signal than a piece of gold of similar size. Thus, it is much easier to detect a very small piece of iron than it is to detect a very small piece of gold.

Finding the small stuff in Greater Detail

The key to the success or sensitivity of a PI to small conductive objects such a small gold nuggets is the ability of the PI circuitry to turn the coil pulse current off very rapidly, and then be able to analyze a signal very shortly after the pulse of current has ended. This sudden stop of current in the coil will cause a very large voltage spike that rises almost instantaneously to some voltage generally between 50 to 400 Volts (V). Generally, the voltage level is a function of the FET (field effect transistor) used to deliver the high current. Once this voltage peaks, it will then quickly decay to very near 0 Volts (0V) in just a few microseconds (usecs). The rate of the decay is extremely important, just as are the characteristics or shape of the decay of this large voltage spike.

One important factor to remember is a large current normally requires more time for the spike to decay. This becomes important when determining the best design for small gold. Another critical factor is the inductance of the PI coil itself. The larger the inductance, the longer the decay time to OV.

It is also critical that this high voltage spike doesn't result in oscillations, which can easily happen. Generally, the coil, for a PI, is made by first determining the desired inductance. Then the coil size or diameter selected. Once the two characteristics are determined, calculations are made to determine the required number of turns of wire to produce the calculated value of inductance.

Once built, the coil of wire is basically an inductor that has some internal resistance. However, because the coil consists of multiple windings, generally a number between 10 and 35, the windings produce a certain amount of capacitance between windings. This capacitance when combined with the inductance of the coil will create a "tuned circuit that will oscillate if additional circuitry isn't added to dampen or stop the oscillation. The basic damping device normally used is a resistor, generally called the damping resistor.

So, by carefully selecting the right resistor, a coil will produce a rapidly decaying voltage spike that doesn't ring or oscillate. If the resistor has too high a value, there will be some very minor oscillation, and if the resistor is too low in value, the spike voltage will take too much time dropping to the OV range.

One other critical part of a search coil that is seldom talked about is the shielding of the coil. Generally, coils have some form of a shield called a Faraday shield. The purpose of this shield is to minimize the capacitive effect between the coil and the ground, reduce static, and to absorb or reduce external noise. Like other factors, the shielding and the technique used, is quite critical. Too much or the wrong type of shielding can reduce sensitivity, especially to small objects such as gold nuggets. Too little shielding will allow other factors such as noise, signal variations due to the ground capacitance, etc to affect the signal. The shielding can also affect the decay time so it can affect the ability to detect small nuggets.

It should be noted that some manufacturers do not use any shielding at all. However, these detectors normally are designed for the detection of very large iron objects so any minor variations in noise or ground capacitance that normally affects very small non-ferrous objects such as small gold nuggets is not a problem. Such detectors normally operate with a very long delay before sampling. This long delay will cause most of the ground signal to be eliminated since it will decay much faster than a signal from a large iron object.

The technical information mentioned above is of little value to the average user of a PI. However, it can be important to anybody who wants to try to build a coil for their detector. The first rule of thumb when trying to build a different coil is to try to duplicate the electrical characteristics of the factory coil. By this I mean, one should try to keep the resistance the same as well as the inductance the same.

How is detection really done?

Both PI's and VLF's take a sample of the receive signal for analysis. In the case of the VLF, the receive signal sample is analyzed with respect to the transmit signal. By doing this, any signal "shift", commonly called phase shift, can be "seen". In other words, the sample is taken by syncing the sample to the transmit signal so the sample is always synchronized to the transmitter. The circuitry used to sample the received signal is normally called the synchronized demodulator.

On a PI, the signal from the coil is initially amplified and some time after the large current pulse is stopped, a sample of the amplified coil signal is taken. Since there is no transmitting going on at the time of the sample on a PI, timing is generally done by waiting a finite time after the termination of the large current pulse and then taking a sample. In this way, there is a form of synchronization also. The time between when the pulse quits and the sample is taken is often referred to the delay time. The delay time on most Gold Hunting PI detectors is 15 usec or less. A delay of 10 usec will show a distinct improvement, especially to very small gold in the few grain range over a detector having a delay of 15 usec.

This delay time is quite critical and is sometimes changed to create a crude form of discrimination, or rather reverse discrimination in the case of gold. As I mentioned before, the signal from gold can decay very quickly. In fact, the signal from most gold nuggets smaller than a 1/4 oz can decay in less than 50 usecs. If the delay is adjusted to 50 usec, then most small nuggets will be ignored, or phrased another way, will not produce any audio response. However, signals from objects made of iron, copper, silver or other highly conductive metal will normally still produce a strong signal. So, if a detector samples the signal at a time later than 50 usec or so, and this sample does not "see" a target, there is a good possibility the object is gold or some other type of low conductive material.

Since the analysis or sampling of this decaying signal is normally only done when the signal gets very near OV, any additional time to drop to the OV level will cause very small gold nuggets to be missed. The reason is because the reflected signal caused by the nugget is very brief and it combines with the normal signal from the coil.

If the nugget signal dissipates before the main signal decays to OV, then, when the sample is taken to determine whether an object is present, the signal from the small nugget will have already subsided and the nugget will be ignored.

Once a sample is taken, this sample voltage is held in suspension, for a better choice of words, until the next sample occurs, which adds to or subtracts from the previous sample. Because of the suspension, normally called sample and hold, and the filtering process built in to reduce noise, multiple samples are required before a true average signal is developed.

Once this average has leveled out, which normally takes a very brief time (in the thousandths or hundredth's of a second), any object that produces a change sufficient to be seen, will cause an additional signal that alters the receive sample average, which then causes the output to change or increase. This subsequent change is further amplified and ultimately is heard as an audio response, normally in a set of headphones.

The Up Side of PI's

Probably the biggest claim to fame of a PI is the additional depth that can be obtained. The key to this is the increased amount of power into the coil that can cause a stronger return signal from a buried object. However, even though there is a significant increase in current, the depth difference between a PI and a VLF isn't as dramatic as one might expect.

Many people question whether this depth advantage between a VLF and a PI is really that great in areas having almost no mineralization but overall, the PI appears to be superior simply because such places are few and far between. Where the PI really excels is in places having a much higher ground mineralization as will as locations where magnetite type hotrocks are common.

Next comes the big debate of just how a PI only using AA batteries can even come close to obtaining the depths of a different PI using a very large heavy duty battery .Obviously, the PI using the AA batteries cannot be pulsing with the same amount of current as a PI using a much bigger battery.

The fact is, the PI that uses AA batteries can approach the depth of other more powerful PI's, especially on gold less than an ounce in weight. There are multiple reasons this can be true. One reason is the fact that there because of a law of diminishing returns, which simply means it takes a whole lot of current to produce a very small depth increase because of shear power alone. As an example, it may take something like 4 amps of current to increase the depth 1 inch over a PI only pulsing with 1 amp, and this is only true if all other factors are equal.

One important factor that determines the sensitivity of the detector is sampling delay time. The sooner a sample can be taken, the stronger the signal that will be seen. In other words, it is quite possible to take a sample sooner and produce a stronger signal on a PI operating with less current than might be seen on a more powerful PI using much more current and having a longer delay. One simple way to allow earlier sampling is to reduce the coil current.

In other words, there are a whole lot of other factors that need to be taken into account to determine what is the best combination. Ah, but someone who just read the previous information might simply say, pulse with a strong signal and then simply sample sooner to make the best detector. Well, unfortunately, the stronger the pulse, the more difficult it is to sample sooner because of the reasons mentioned before. A longer pulse or lower coil resistance will result in more coil current, which will affect how long it takes for the spike to decay. A larger inductance will also result in a longer decay time. In fact, it becomes almost impossible to obtain the very short delay times when using a very strong pulse of long duration.

One way to help shorten the delay time of the decaying pulse is to reduce the number of turns of wire in the search coil. However, the field strength of the coil produced when current flows in the coil is a function of both the current and the number of turns, so reducing the number of turns also reduces the field strength produced. So any reduction in number of turns directly relates to potential depth loss.

If all this seems confusing, it is. Not only does the actual current have an effect, but the actual pulse length or time the current flows has an effect as mentioned before. Therefore, it is possible to pulse fewer times and use a shorter pulse and obtain very satisfactory results.

Pulse lengths of 50 usec or less will still produce a very decent signal from most of the gold nuggets that are found with a detector. Increasing the pulse length to 200 usec will really only have an impact on the signal coming from very large gold objects. The reason why the large increase in pulse time doesn't help on most smaller gold is simply because most of the smaller gold is fully saturated by the shorter pulse. Any additional pulse really does nothing to the potential signal that will come back form that gold object.

As a general rule though, a more powerful PI having a very long pulse will generally go deeper on very large gold, meaning nuggets weighing several ounces or more will be more readily detected to greater depths.

A detector using a high current short pulse will have a tendency to be more sensitive than a detector using less current. However, this difference normally is not dramatic, if at all. The key lies in early sampling and noise reduction.

One other major advantage of a PI over a VLF is the fact that many of the hotrocks or black sand that make a VLF Scream will cause little or no signal on a PI. Normally, these intense hotrocks create a response on a VLF because of the magnetite within the rock.

A PI will seldom create a response to a magnetite rock or black sand due to the fact a magnetite hotrock or black sand signal will normally dissipate well before a sample is taken. However, an unbalanced earth field effect elimination can cause a hotrock to create some response, as can a very quick sample. In the case of some of the PI kits people build, where there is no earth field effect

However, this subtraction process is seldom perfect and because the sample is taken at a different point in time, there will always be a very slight response that just might cause a very slight increase or decrease in a target response. Most likely this will occur or be noticed on the targets just on the threshold of detection. However, if for some reason the subtraction process is not near perfect, then it is quite possible that there will be a noticeable increase in signal strength when passing over a target from one direction than when passed over on the opposite direction of the coil swing.

The earth field effect is one of the reasons there may be a slight response at the end of a coil swing. The sudden stop of the coil before moving the opposite direction produces a much stronger EFE signal. One should also remember that it is almost impossible to totally eliminate the EFE so some of the minor responses mentioned should be considered normal.

One final noise problem is the noise generated within the detector itself. Just due to the nature of the circuitry used, a lot of noise is generated within the electronic circuitry .Much of this noise is "filtered" by the battery and aided by large capacitors and other filtering devices such as ferrite cores. However, no battery or capacitor is perfect so some noise always gets through.

The result of all the combined noises commonly creates a form of chatter or warble that can significantly reduce the sensitivity, especially to very small or deep objects producing very weak signals. In many cases, the noise may not even be really noticeable but be of sufficient amplitude to cause a reasonable depth loss.

Ground signals and Ground Balance

PI's are susceptible to many types of ground conditions, and, depending upon the type of ground, the sensitivity, and the delay, may generate a very strong signal due to the ground.

Terms like magnetic viscosity are used to explain just why certain types of ground can cause a strong response. Ground conditions having concentrations of maghemite will create very strong ground signals.

Areas having a clay base seem to produce strong ground responses also indicating that clay itself is part of the problem. Articles such as those written about geophysical research indicate that the clay problem can vary dramatically because of the type of clay as well as the moisture within the clay.

An article written by the Army Corps of Engineers indicates that clay will actually create a field that opposes the transmitted field of the PI and moisture enhances the ability for the clay to oppose the field due to the ionic behavior within the clay.

Coils, Coils, and more Coils

VLF's always have a transmit coil and a separate receive coil of wire in the search head. PI coils, however, can be produced in several variations. If the same coil is used for both the transmit and the receive signal, the coil is normally called a "MONO" coil.

If two sets of coil windings are used, and those coils are basically the same size and shape with one coil used as a transmit and the other the receive, and they overlap a small amount on one side, the coil is generally called a DD coil. The name DD generally refers to the design of the coils where they are sort of like D's with one D reversed and the backs of the D's overlapping slightly. This overlap area is the main detection zone and is the area where an object is under at least part of both coils at the same time. This detection zone is most noticeable on deeper objects.

By nature, DD coils are somewhat less sensitive when compared to a mono coil of the same size. One reason for the reduction in sensitivity is the fact that the DD electrical coil windings are smaller in size than the coil windings of a mono coil even they may have the same size coil housing.

One other key factor that is important is the fact to remember about a DD coil is the main detection zone is quite narrow. This narrow detection zone, normally at or near the overlap will create a very brief or narrow signal when compared to the signal on a mono coil. This situation makes the sweep speed of the search coil much more critical. Swinging the coil too fast can easily cause a very weak object to be missed simply because the signal is so short and the circuitry filtering used to eliminate the noise will also almost eliminate such a signal.

The fact that DD coils have smaller diameter windings for the transmit and receive coil, when compared to a mono coil using the same size housing, has some advantages. Generally, the smaller receive coil is not as good of an antenna as a larger mono coil, thus less noise is detected and amplified. As a result, the detector can be much quieter when using a DD coil. In many cases the reduction in noise can outweigh the depth loss due to the size difference.

One other major asset of a DD coil is the fact the receive coil is isolated from the transmit coil. This helps in the fact that any low level noise that is generated by the transmit circuitry during the sampling time is isolated from the receive circuitry. This isolation therefore reduces the combined noise that can negatively affect a target response.

One final advantage of a DD coil is, by nature, a DD coil partially cancels the ground signal. If the coils are properly aligned or positioned, most ground signal in the receive coil is eliminated. This results in a detector that has very little ground response, yet still responds with a strong signal from a buried object.

Another type of coil that is made for PI's is called the figure 8 or "Salt" coil. In this design, there is a large transmitting coil and two receive coils that are wired such that the receive coils are opposite of each other, meaning that one coil will produce a positive signal and the other a negative signal. On this type of coil, it is quite common to build a larger receive coil, elongate it, pinch the center of the elongation and then twist one half of the receive coil one half turn to create two coils, much like a figure 8. As mentioned before, this type of receive coil is also called a "figure 8 coil" just due to how it is constructed.

One advantage of a "salt" coil having a large transmit coil and two smaller receive coils is the design is both ground canceling and noise canceling. The ground canceling relies on the principle that both receive coils are equally spaced from the ground for maximum ground signal elimination.

The disadvantage of the Salt or figure 8 coil is there is a depth loss that occurs when compared to a similar sized mono coil or even a similar sized DD coil. Part of the reason for the depth loss is the fact the two receive coil signals basically oppose each other since one will produce a positive receive signal and the other will produce a negative signal. This opposition will cause some receive signal to be eliminated.

Because the signals from two receive coils have a tendency to cancel each other, any noise detected by the two coils basically is also canceled. This cancellation process has one other advantage and that is, it will eliminate the earth field effect.

A little different figure 8 coil can be built where there is only one coil used as both the transmit coil and the receive coil. This coil is again, elongated, pinched, and one half of the coil is twisted over so half of the coil is transmitting up when the other coil is transmitting down. This type of coil eliminates or cancels external noise extremely well but does not ground cancel. Since the two xmit coils are much smaller, there is also some depth loss on this type of coil because of the size of the coils as well as the signal from the two halves of the coil have a tendency to cancel each other. As such, the signal from a buried object will be the greatest when it is centered or near centered under either of the two coils and the weakest when the object is right at the crossover point of the two coils.

One of the most common coils found on a VLF is something called a concentric coil. In this case there generally is a large transmit coil and a smaller receive coil basically centered in the large coil. For this type of coil to really work correctly on a VLF, there will be an additional transmit coil wound directly on the smaller receive coil, but will wound opposite to the main transmit coil. The purpose of the smaller transmit coil is to cancel any signal in the receive coil caused by the larger transmit coil A concentric coil design can be used for a PI, but it is rare to find one..

Of course, there can be variations of the above coils, meaning they can be rectangular, round, oval, or any other shape a person should desire. Also, the windings can be changed or possibly additional windings can be incorporated to produce the desired results. So, the ultimate design of a search coil is left to the imagination of the designer.

Finally, some mention has to be made regarding coil size. The coil size of most PI's normally ranges from an 8" diameter coil to greater than 3 feet in diameter. It is quite common to hear of a person using an 18" diameter coil, but the most popular sizes range from 11" to about 14".

Recently, Eric Foster posted some interesting findings regarding the general detection ranges of different sized coils versus target or object size. This information can be viewed on the PI forum and displayed on September 16, 2002. Several discussions occurred during that time pertaining to the depth verses coil diameter, versus target size.

As one might expect, the larger the coil, the deeper one may find objects. However, it is quite possible a smaller coil will find an object deeper than a large coil, especially if the object is small. Contrary to the some of the discussion that resulted on the above mentioned forum, there is a more direct relationship between the size of the coil, size of the object and the ideal maximum depth such an object can be detected. An error in calculations led to some information being incorrectly noted.

One should realize that information such as what Eric Foster posted is generally theoretical and as such is subject to some distortion in the real world. However, as a rule, the general principle is quite accurate.

When searching for information about depth or size of objects that can be found with different size coils, extreme cases always show up. For example, many people have found extremely small nuggets ranging in the few grain range with an 18" coil. Normally such a large coil will not be able to see such a small target at any depth, or even in the middle of the coil if the nugget is small enough. However, this small nugget can produce a signal if it is very near the coil windings themselves.

One final point that I am sure will cause controversy and that is a smaller coil will not show as dramatic increase to sensitivity to small gold on a PI like it does on a VLF. The reason, again, lies in the fact that the sensitivity to small gold on a PI, is much more dependent upon the delay before sampling than it is on the coil itself.

Finally, Discrimination on a PI

Due to the nature of the signals caused by different objects, it is extremely difficult, or put another way, almost impossible to build a good discriminating PI.

Since the time it takes for a target signal to decay can vary because of the size, shape, and chemical makeup of the object, then any type of later sampling will not produce a reliable form of discrimination.

Many PI's rely on the ability of an adjustable delay whereby the operator can simply adjust the delay longer to see if an object is a piece of gold or not. If the delay is increased and the signal from an object disappears, then the operator can assume the object is made of a lower conductive material such as gold. This is acceptable for those hunting something like gold rings, but does not work well on gold nuggets. Larger gold nuggets can produce a much longer delay, so any attempt to use this delay technique will result in one thinking a large gold nugget to be junk.

Another concept used on a PI for discrimination is to sample during the "on" time of the pulse. Any target will produce a slight change in the signal seen at that time as well as a change when the normal target sample is taken.

If the analysis is done correctly, then one can use both the "pulse on" and "pulse off" signals and get a better analysis of a target. This type of design can lead to a better form of discrimination. However, few if any PI's are actually using this technique.

Regardless of the technique used, no form of discrimination is perfect, and, most likely, never will be. Some techniques are better than others, but all can be fooled, and this is true of both PI's and VLF's.

By Reg Sniff